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CERTIFICATE

This is to certify that the work embodied in this thesis entitled **"Studies on allelopathic potential of Subabul (*Leucaena leucocephala* Lam de vit)"**, submitted by **Ms. Neelam Khare,** for the award of Degree of **Doctor of Philosophy** to the Bundelkhand University, Jhansi, has been carried out under my supervision and guidance, that the work embodied has not been submitted elsewhere for the award of any other Degree or Diploma and is up to the mark both in its academic contents and the quality of presentation.

This is also certify that **Ms. Neelam Khare** has put in the attendance required under the statutes of the university during the course of the present investigation.

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DECLARATION

I hereby state that the present work entitled **"Studies on allelopathic potential of Subabul (*Leucaena leucocephala* Lam de vit)"** has been carried out by me under the supervision and guidance of Dr. A.K. Bisaria, Senior Scientist, (Plant Physiology), National Research Centre for Agroforestry, Jhansi and to the best of my knowledge, a similar work has not been carried out any where so far.

Dated: 10·8·2000

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I affirm all the responsibility for its shortcomings and limitations.

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LIST OF CONTENTS

List of Tables

List of Figures

List of Photoplates

EXECUTIVE SUMMARY

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The present investigations entitled "Studies on allelopathic potential of Subabul (*Leucocephala leucocephala* Lam De Vit)" were carried out from 1997 to 1999 in the laboratory and at the experimental farm of National Research Centre for Agroforestry, Jhansi, U.P. The studies were conducted keeping in view the increasing importance and interest of agroforesters in allelopathy. Trees are found growing on farm boundary, either natural or man-managed, since ancient times. Neighbouring plants may interact with the growth and development of other plant species. The interaction between two species may be negative or positive. The effect of one species on another is referred as **allelopathy** which is derived from two Greek words ***'Allelon'*** means mutual and ***'Pathos'*** mean harm which generally refers to the detrimental influence of higher plants, of one species (the donor) on the germination, growth, development and/or yield of plants of another species (the recipient).

Therefore, the choice of species combinations may affect the productivity and ultimate success of agroforestry system. In this context, *Leucaena leucocephala*, one of the most important multipurpose tree species of Central India and is being preferred by the farmers of this region to meet their requirements of fodder and fuelwood. Therefore, the present studies were undertaken to elucidate the allelopathic influence of *Leucaena leucocephala* on *Triticum aestivum* and *Glycine max*. The studies was conducted in three main experiments *viz*. allelopathic studies in laboratory, nursery and field conditions. The results obtained from these studies have been summarized on the succeeding pages in this chapter.

Allelopathic influence under laboratory conditions :

The aqueous extracts of *L. leucocephala* leaves, flowers and pods were prepared as per the standard methods and diluted to get 20, 40, 60, 80 and 100 concentrations were obtained. The influence of aqueous extract was determined on the seed germination and seedling growth of wheat (*T. aestivum*)and soybean (*G.max*) under laboratory conditions. The germination was initiated on 3rd day and its speed accelerated thereafter. The process of germination ceased on 10th day. The data were recorded for germination percentage, root, shoot and seedling elongation, fresh and dry weight of seedling. The salient findings of the laboratory studies were:

- The laboratory studies exhibited that aqueous extract of fresh leaf stimulated the seed germination and seedling growth of *T. aestivum* and *G. max* up to a concentration of 40% and inhibited significantly at 80-100% concentrations over control.
- The trend for shoot -root ratio showed that concentrations of 20 and 40% increased, non-significantly affected at 60% and reduced drastically at 80 and 100% concentrations.
- The aqueous extracts of flowers and pods exhibited the same trend and maximum stimulation for all the parameters of seed germination and seedling growth recorded at 40% concentration.
- The decomposed leaves extract significantly promoted seed germination, seedling growth and productivity parameters at lower concentrations (20-40%) had non significant effect at 60% concentration and inhibited at higher concentrations (80-100%).
- Mimosine concentration was estimated in fresh leaves, flower, pods and decomposed leaves. The maximum amount of mimosine

was estimated in pods and minimum in decomposed leaves. The overall trend for mimosine concentration was pods (7.13%) > flowers (6.87 %) > fresh leaves (5.53) > decomposed leaves (4.61%).

- The pattern of influence on both the crops revealed that maximum inhibition was due to aqueous extract pod followed by flower, fresh leaves and decomposed leaves. The stimulatory effect was more pronounced in *T. aestivum,* where as inhibitory effect was significant higher in case of *G. max.*

Allelopathic influence under nursery conditions

The results obtained under laboratory conditions revealed that there was allelopathic influence of *L. leucocephala* on both the companion crops. Further, to confirm these results an experiment was conducted under nursery conditions. The experiment involved the soil collected beneath the *Leucaena* plantation in combination with field - soil. The *Leucaena*- soil was mixed with the field -soil at four level *viz Leucaena* - soil only(1:0); *Leucaena* -soil + field -soil in 1:3; *Leucaena*- soil + field- soil in 1:1 and field -soil only (0:1). Three kg of soil of each combination was filled in polythene bags. Observations were recorded on seed germination, shoot, root, seedling elongation and shoot -root ratio. The results are summarised below :

- The maximum seed germination (84.33%) was recorded for 1: 3 ratio which was at par with field-soil treatment. The minimum germination was observed in Leucaena- soil only (51.66%).
- The length of shoot inhibited gradually, after reaching maximum (21.35cm) at 1:3 ratio, with increase in amount of *L.*

leucocephala- soil and minimum shoot length was recorded in *L. leucocephala* -soil only.

- The length of root was affected more adversely then that of shoot in all the treatments for both the crops.
- The fresh weight of shoot and root was only enhanced in a mixture of *L. leucocephala*- soil + field -soil (1.623g) in 1 : 3 ratio, while other combinations reduced this attribute both in shoot and root.
- The soil combination treatment decreased dry weight in shoot, root and seedling in all the combination except of *L. leucocephala* -soil + field soil in 1 : 3 ratio, where the effect was found to be positive. The moisture contents in shoot, root and seedling in terms of weight was promoted in the same treatment and reduced in other combinations. However, the percentage of moisture in shoot, root and seedling was not affected by any of the combination.
- The inhibitory influence on seed germination in *G. max* was more pronounced due to *L. leucocephala* -soil as compared to *T. aestivum*.

Allelopathic influence under field conditions

The field studies were conducted during 1997-1999 to determine the influence of *L. leucocephala* trees on *T. aestivum* and *G. max*. The observation were recorded on the growth and physiological parameters of tree as well as growth, physiological and yield parameters for both the intercrops. The important findings of the field experiment are as follows:

- The growth parameters of *L. leucocephala viz.* tree height and collar diameter were examined during 1997-98 and 1998-99. The

influence of different seasons on the height of tree exhibited that the trees pruned and applied with mulch in association with intercrop attained maximum height (286.75and 495.81cm)while the sole tree attained minimum height (219.18 and 348.19cm) in *L. leucocephala* during 1997-98 and 1998-99 respectively.

- Almost similar trend was exhibited by collar diameter of *L. leucocephala* .The values for sole tree and tree + crop did not show significant difference during different seasons in *L. leucocephala* in both the years. The maximum increment in collar diameter for *L. leucocephala* were recorded for treatments tree pruned + mulch + crop (2.61 and 6.05 cm) where as, the minimum values (2.10 and 4.41cm) were recorded for sole tree treatment during 1997-98 and 1998-99 respectively.

- Physiological parameters *viz.* leaf temperature, relative humidity, photosynthetically active radiation (PAR) and rate of transpiration of *L. leucocephala* leaves were determined. The results exhibited that the leaf temperature and relative humidity, were significantly increased in case of tree in association with crop as compared to sole tree during all the seasons. The maximum value of leaf temperature was 44.4^{0}C in May and minimum 18.5^{0}C during Feb. The maximum relative humidity was observed in August (82%) and minimum (27.2%) in the May.

- The data indicated that PAR was maximum (1091and 967μ mole/ sec cm^2) in May followed by November and February with and minimum (835 and 790μ mole/ sec cm^2) in August, in sole tree as well as tree + crop, respectively. However, the value for PAR were significantly higher in case of sole tree irrespective of season then tree + crop. The rate of transpiration was higher in tree +

crop as compared to sole tree while the value were not significantly different during August, November and February.

- The growth parameters *viz.* plant population per meter row, plant height, number of branches per plant in *G. max* and *T. aestivum* were significantly reduced due to *L. leucocephala*. However, the maximum increments for these parameters were recorded for treatment in which crop was applied mulch compared to sole crop. The reduction in aforesaid parameters was checked to some extent by pruning of trees with supplemented with mulch.
- The yield parameters such as number of flowers, pods / tillers and grain yield exhibited that the maximum values were observed for the treatment when crop was applied mulch and minimum in the tree + crop treatment. Thus, the yield parameters can also be enhanced in the same way as growth parameters by pruning and mulch application.
- The allelopathic influence of *L. leucocephala* on growth and productivity of intercrops was more profound during second year as compared to observations of the first year.
- Soil analysis revealed that on an average, organic carbon, available N, P and K increased to 0.54%, 241.62, 17.27 and 325.94 kg/ha, respectively against the initial values of 0.46%, 214.85, 15.19 and 298.70 kg/ha, respectively. Among the various treatments maximum organic carbon (0.61%), N (260.90 kg/ha), P (19.83 kg/ha) and K (340.81 kg/ha) were estimated in tree pruned + mulch + crop and minimum (0.50%, 225.11, 16.00 and 319.64 kg/ha, respectively) in sole crop.

It appears from the field studies that reduction in crop growth and yield parameters caused by tree of *L. leucocephala* can be contest

effectively by pruning of tree and mulch application. Moreover, reduction in crop yield can be further compensated to some extent by the leaf, fodder and fuelwood received due to pruning of the tree.

The present studies revealed that the allelopathy may not be an universal explanation for regeneration failures, delayed seed germination, retarded seedling growth and reduction in productivity but is also not an ignorable phenomenon. The allelopathy could have a pronounced effect on simultaneous system of agroforestry where tree component is a permanent feature and release chemicals continuously into the environment which directly or indirectly affect the companion crops. The important allelochemicals *viz* mimosine, quercetin, gallic acid, ferulic acid and verulic acid are released into the environment through leaching, root exudation, volatilization and decomposition of plant parts.

The allelopathic influence *L. leucocephala* was more pronounced in laboratory compared to nursery or field conditions. The allelopathic influence under field conditions can be managed effectively to enhance the productivity of the companion crops through proper management practices such as pruning and mulch application.

It appears from the experimental findings that the allelopathic influence of *L. leucocephala* on *G. max* and *T. aestivum* is mediated mainly through mimosine, which perhaps lead to inhibition of seed germination, seedling growth and yield of companion crops. Stimulation of growth and productivity at lower concentrations and inhibition of these attributes at higher concentration of mimosine may be explained by suggesting that mimosine, an amino acid has a wide spectrum of its influence and also plays a decisive role in manipulation the growth and yield attribute of companion crops. It is evident from the observation of

the experiments that the allelopathic influence was more pronounced in laboratory studies compared to nursery and field conditions may be attributed to biodegradation of mimosine and other chemicals during their release and transportation by biophysical factors *viz.* light, temperature and biodegradable efficacy of microorganism.

INTRODUCTION

INTRODUCTION

India has a geographical area of 328.92 million hectares of this 142 m ha are under crops and about 45 million ha of the cropped area are irrigated. The average per capita land holdings are about 0.43 ha and cropping intensity is 125%. The climatic conditions are favourable for round the year cropping. In view of the diverse soil type and agroclimatic conditions different types of agricultural practices and cropping systems are followed in various parts of the country. Multicropping, intercropping and agroforestry are practiced mainly to increase crop productivity per unit area and time and also to compensate for initial slow growth period of the main crop as it is complementary in the use of growth resources. Generally, short duration field crops or vegetables are grown between the widely spaced multipurpose tree species.

India is losing about 50 million tonnes of food grains, every year on account of the loss of top soil caused by deforestation. The conversion of forest land to meet the food grain requirement of continuously increasing human population is one of the most important factors for deforestation.

Agroforestry is the major safeguard for lean periods by providing agriculture crops in association with trees which are very much useful for fuel, fodder and timber. In agroforestry systems woody perennials are deliberately introduced or retained in fields/farms with crops or pastures in a variety of spatial or temporal arrangements. Therefore, the choice of species combinations may profoundly affect the productivity and ultimate success of some agroforestry system. In agroforestry system interference may result from competition, allelopathy and/or other indirect influences. Competition is the phenomenon by which plant

utilizes limited resources such as light, water or nutrients from the environment, therefore, affecting the survival and/or growth of a neighbouring plant. Allelopathy is the phenomenon in which natural products (secondary metabolites) are released into the environment which subsequently reduces or enhances the survival and/or growth of neighbouring plants. Agroforestry is a relatively new field and less work has been conducted on species compatibility (Wood, 1988). Currently, some species used in agroforestry systems are reported to exhibit allelopathic properties (Waternabe *et al.*, 1988). Tree species are grown on farmers field since ancient times, either natural or in man managed agroecosystems. Neighboring plants may interact with the growth and development of other plant species. The interaction between two species may be negative or positive. The effect of one species on another is referred as allelopathy.

The word **allelopathy** is derived from two Greek words *'**Allelon**'* means mutual and *'**Pathos**'* mean harm which generally refers to the detrimental influence of higher plants, of one species (the donor) on the germination, growth, development and/or yield of plants of another species (the recipient). It can be separated from other mechanisms of plant inhibition because the detrimental cause is exerted by chemicals released (allelochemicals) by the donor species into the plant through environment. It is, therefore, different from competition which involves the removal or reduction of some growth factors from the environment that is also required by some other plant, sharing resources from same habitats such as water, nutrients and sunlight. Thus competition occurs when two organism have to share the same limited resource at same time thus reducing the availability of that resource for one of the organism.

Confusion surfaced because some biologist considered allelopathy to be a part of competition.

The impact of allelopathy in agriculture was recognised for the first time by Theophrastus in 300 B.C. who is referred as father of Botany. He stated, "chickpea (*Cicer aretinum*) does not reinvigorate the soil as other legumes do but exhausts it instead". Further, he pointed out *"Cicer aretinum* inhibit the growth of weeds and destroy them". Pliny in the first century A.D., reported that *Cicer arietinum*, *Hordeum vulgare, Trigonela forenum-graecum* and *Vicia ervilia* all `scorch up' cornland and that *Juglans nigra* causes headache in man and injury to any thing planted in its vicinity. This may be possible that these plants release certain chemicals in to environment affecting the growth of other plants. Allelochemicals originating in foliage, leaching root products or mulches of crops/ woody plants may result in reduced productivity or even leading death of companion plants. Some plant species are widely known for their allelopathic interference with field crops. Plant residue mulches commonly used in agroforestry system, to protect soil erosion, conserve moisture and supply of nutrients (nitrogen) may be the potential source of allelochemicals that interfere with crop productivity.

Molisch (1937), a renowned Plant Physiologist coined the term **allelopathy** which refer to all biochemical interactions (stimulatory/ inhibitory) among all kind of plants, including microorganism. It represent, the plant- plant interactions a vistas of chemical ecology. Mullar (1969), suggested the term interference including micro-organism on another. The potential cause of interference are :

(a) allelospoly (competition) which involve depletion of one or more growth resources viz. sunlight, moisture, nutrients and space.

(b) allelopathy- that is addition of toxin from one or more plant microbial species that reduces or enhances the survival or growth in association and

(c) allelomediation -selective harbouring of a herbivore that might selectively feed on one species to another (Tomer and Srivastava,1986).

Since the beginning of research in this field, the scientists used different terms, *viz* **competition** or **allelospoly** which created confusion. Therefore, to avoid this confusion the various scientists defined the term allelopathy. Some of the important definitions are as follows :

1. Molisch(1937), coined the term allelopathy to describe all the biochemical interactions among plants (microbes and higher plants), stimulatory as well as inhibitory.
3. Bonner (1950), describes that "It includes interspecific (antibiotic) as well as intraspecific (autotoxic) chemical coaction.
3. Muller(1969), refers the allelopathy to deleterious effects that one higher plant as on another through the production of chemical retardants that release into the environment.
4. Delmoral and Cates (1971), stated it as "inhibition of germination, growth and metabolism of plant due to the release of organic chemicals by another".
5. According to Rice (1974), allelopathy refers to any direct or indirect inhibitory effect by one plant (including microorganisms) on another through the production of chemical compounds that escape into the environment.
6. Tischler (1975), describe that "it is interspecific chemical co-action, while autoallelopathy is intraspecific chemical coaction."
7. Putnam and Duke (1978), defined allelopathy as "detrimental

effects of higher plants of one species (the donor) on the germination, growth and development of another (the recipient) plant species."

8. Annonymous (International Allelopathy Society,1996), has recently proposed a new definition of allelopathy which refers to any process involving secondary metabolites produced by plants, microorganism, viruses and fungi that influence the growth and development of agricultural and biological systems (excluding animals).

The aforesaid definition is the most acceptable one because it covers all vistas of this new science, which has a wide spectrum of role in agriculture, horticulture, forestry and agroforestry. Considerable research work on allelopathy has been done in developed countries and has been implicated in major problems related to crop production, horticulture and forestry. Allelopathic studies has also been initiated in India and some significant information has been generated. Influence of one plant on another was reported by Rice (1984). Numerous allelochemicals are released from plant primarily through leaching from above-ground parts and affects the chemical properties of soil. It has been ascertained that dominant plant species exert influence on the floor conditions and nutrient availability. However, now, it is evident that allelopathic effects play a major role in the development of species and community structure under the canopy of that particular species.

Allelopathy has currently been gaining spectacular acceptance in India as a factor having ecological significance in plant dominance, patterning of vegetation (Melkania, 1992). Succession, crop productivity and agroforestry system and a number of species with

allelopathic potentials have been identified (Parihar, 1985; 1994; Melkania, 1994). Recently, Narwal (1996), has nicely reviewed the work conducted through out the country on the production of chemicals that defused into the environment and possess allelopathic potential in relation to agroforestry systems.

The inoculation of seeds or plant with living non-pathogen prevents attack by pathogen in many cases. There is much indirect evidence from *in vitro* experiments that antibiotics are involved but it is difficult to detect antibiotics under field conditions. The production of antibiotics is important in many of the reported cases of antagonism to various plant diseases.

Allelopathy in natural ecosystem

It appears that the allelopathic effects are of ecological significance affecting dispersion of plants and thus the patterning of vegetation. Various parts of *Pinus densiflora* and soil under it were found to contain chemicals toxic to many understorey plants. The allelopathy play an important role in suppressing understorey growth beneath many plant species.

Patterning of vegetation

The most of the allelopathic effects are of ecological significance influencing dispersion of plant and therefore the patterning, for example as in the case *Polygonum aviculare* rapidly encroaches into bermuda grass lawns and the grass dies in patches of *Polygonum aviculare* while bermuda grass at the edges of the *Polygonum aviculare* patch turns yellow.

Pinus densiflora forests are widespread in Japan and covers about 60-70% of forest land in South Korea (Lee and Mansi,1963). Various parts of *Pinus densiflora* and the soil under it were found to contain some chemicals which are toxic to many understorey plants. Thus, it was concluded that allelopathy play an important role in retarding understorey growth therefor, determines the patterning of vegetation in the ecosystem.

Plant succession

There are four main successional stages *viz.* pioneer, annual, perennial and climax stage.The evidences are strong that the pioneer weed stage disappear rapidly because the species are eliminated through strong allelopathic interactions (Rice,1984). *Aristida oligantha*, *Prairic threeawn* are the dominant species of the annual stage and invades the entire area apparently because they were not inhibited by the allelopathic chemicals produced and were able to grow well and reproduce in soil that was still too low in nitrogen and phosphorus to support species that invade later in succession namely perennial and climax stages (Rice *et al.*,1960). *Aristida oligantha* and several pioneer species produced allelochemicals which inhibit growth of *Rhizobium* free living nitrogen fixing organism, nodulation and hemoglobin formation in legumes (Rice, 1984). This indirect evidences suggested that the rate of biological nitrogen fixation was slowed in the first two stages of succession. Kapustka and Rice (1976), measured nitrogen fixation rates in soils of the pioneer weed stage, the annual grass stage and the climax prairie using the acetylene reduction technique. Rice and Pancholy (1972; 1973), found that concentrations of nitrate decreased from a high value in the first succession stages to a low value in the

climax stage, whereas concentrations of ammonium nitrogen increased from a low value in the first stage to a high value in the climax stage. Moreover, the counts of nitrifers were high in the first successional stage and decreased to a low in the climax prairie. Thus, nitrate nitrogen is readily leached below the depth of rooting, moreover, nitrate has to be reduced back to ammonium before it can be used by the plants and this requires energy. Eventually, the nitrogen concentration increases to the point where climax species can invade.

Weed succession on urban waste land is similar to that in old fields in some parts of the U.S.A. with *Ambrosia artemissifolia* being the first year dominant weed followed *Solidago altissima* and *Erigeron* for a few years and next by *Miscanthus sinennis.* Numata *et al.*, (1975), reported that *Solidago altissima* and *Erigeron annuses* both produced polyacetylenic methyl esters which inhibit seed germination of *Ambrosia artemissifolia, Miscanthus sinensis* and a species of *Tagetes* and growth of rice seedlings. The Phytotoxin detected in *Solidago* was also extracted from soil in a stand of the species and the concentration present was sufficient to regulate germination and growth of associated species. A dilute solution of 5 ppm of three viz of the phytotoxins inhibit growth of *Ambrosia artemissifolia* in soil.

Allelopathy in forestry

There are some examples which indicate that forest species produce certain chemicals which inhibit or stimulate the growth of associated species. Tubes (1973), found that sugar maple seedling inhibit growth of seedling of yellow birch despite the apparent absence of competition in nursery experiments. Jobidan and Thibault (1981),

observed growth depression of *Alnus* near *Populus balsamifera* stands. Certain tree species such as *Betula pendula* and *Picea abies* develop in association with *Calluna vulgaris* (Handley, 1963; Robinson, 1972). This apparently results from the production by heather of an allelochemical toxic to growth of mycorrihizae of *Betula pendula* and *Picea abies.* Fruticose lichens are often allelopathic to the growth of mycorrihizae and forest tree seedlings. *Alnus* species are often important in forest because of the fixation of nitrogen by *Frankia* in nodules on their roots.

Allelopathy in agriculture

When some crops grow with the other crops or weeds with crop or tree they affect each other whether the effect is stimulatory or inhibitory. Yield of *Glycine max* increased by burning the *Oryza sativa* straw prior to the sowing of planting the *Glycine max (*Joshi, 1991). *Cassia uniflora* is a good biological control plant for *Parthenium hysterophorus* and replaced that weed in some part of India. The replacement has been due to a combination of allelopathic factors. Over 100 species of weeds have been identified to have allelopathic potential. There are several evidences that yield of a particular crop is increased or decreased by adopting a particular crop rotation. It is only due to the allelochemicals released in the soil or atmosphere by that crop rotation. Some crop residues appear to stimulate growth of other plants. Chopped alfalfa added to soil stimulated the growth of tomato, cucumber and several other crops (Ries *et al.*, 1977), the stimulatory allelochemical was identified as triacontanol. A steroid, brassinolide was isolated from *Brassica napus* caused significant growth increase in bean.

Allelopathy in plant pathology

The Parasitic plants belongs to several families and seed germination appears to function as one level of chemical recognition in host selection. Johnson *et al.*, (1976), reported that the synthesis and testing of several analogues of strigol and were found powerful seed germination stimulants for species of both *Striga asiatica* and *Orobanche* a root parasite. Stimulation of seed germination of parasites in soil even in absence of host plant when host plants was not present, prove to be a good control mechanism. The inoculation of seeds or plant with living non- pathogens prevent attack by pathogen in many cases. The production of antibiotic is important in many of the reported cases of antagonism to various plant diseases.

Allelopathy in weed control

Weeds are a major problem of Indian agriculture owing to a favourable climate for plant growth round the year and chemical weed control being practised only in *Oryza sativa* and *Triticum aestivum* and that too only in limited areas. There are more than 100 weed species of field crops, some of them are very harmful to crops and cause huge losses in crop yields. Allelopathic interactions between crops and weeds are partly responsible for such crop losses. Screening of crops for their smothering effect on these weeds may control them without herbicides. In *Brassica carinata* BCCN-2 recorded the least population (50%) and dry matter accumulation (34.2%) of weeds compared with other genotypes and control (Sarmah *et al.*, 1992). Studies have shown that *Pennisetum typhoides* provides 93% control over *Trianthema portulacastrum* weed compared with *Sorghum bicolor, Zea mays, Vigna*

unguiculata and *Cymopsis tetragonoloba* (Sarmah,1992). This reflects that weeds can be controlled effectively be certain crop species as they are releasing allelochemicals in the soil. Allelopathy partly provides protection against decay and imparts the dormancy to weed seeds present in the soil and thus they remain viable for several years. The weed seeds contain antimicrobial compounds and germination inhibitors. The weeds affect crop plants through release of phytotoxins from seeds, decomposing residues, exudates, leachates and volatile; however weed residues are the major source of phytotoxin in the soil. Thus allelopathy can be used effectively to reduce the weed population in the field.

Allelopathy in agroforestry

It is now established that trees suppress the growth of certain understorey or neighboring plant species. Allelopathy play a significant role in agroforestry, crop growth, development and productivity. In crop production, it is related to problems of soil sickness, autotoxicity, predisposition of plants to disease, prevention of weed seed decay, reduced biological nitrogen fixation in legumes and uptake of nutrients. In trees, it causes autotoxicity, failure of budding/ grafting and suppression effect on understorey species. The allelopathic effect is due to allelopathic compounds and (secondary metabolites) which are produced by trees, bacteria, fungi and algae under agroforestry system. *Leucaena leucocephala* is known to have allelopathic effect on the intercrops such as cereals, legumes and grasses.

Chemical nature of allelopathic compounds

Allelopathic compounds belongs to a wide variety of chemical groups which originated either through the acetate or schikimic acid

pathway .These compound ranges from very simple gases and aliphatic compounds to complex multi-ringed aromatic compounds. Knowledge of the chemicals involved in allelopathy and their nature is crucial to understand the basic phenomenon of allelopathy and there is a need to discover much more about chemical nature of these compounds.

Allelopathy plays a significant role in different vistas of plant sciences. In the near future allelopathic interactions may be used to increase productivity of agroecosystems, maintain soil health productivity, reduce environmental pollution and to develop stable, highly productive and sustainable agricultural, horticultural and agroforestry systems. Allelopathic potential of some important and valuable tree species commonly planted in agroforestry systems is briefly described as follows:

Eucalyptus **:** Although, Learner and Evenari (1961), reported presence of germination inhibitors in the leaves of *Eucalyptus rostrata.* Del Moral and Muller (1970), were the first to study the allelopathic effect of *Eucalyptus camaldulensis* and *Eucalyptus globulus* in the bare area under these trees in part of California. They demonstrated that light, nutrients and moisture etc. were not responsible for the bare areas but the leaf leachate had inhibitory effect on vegetation beneath the tree canopy. Like wise, allelopathy suppressed the growth and development of species beneath the *Eucalyptus* canopy in Australia (Bowman and Kirkpatrick, 1986; Lovett, 1986). Allelopathy is the cause of suppression of understorey vegetation due to *Eucalyptus* sp. especially in drier climates (May and Ash,1990; Bowman and Kirkpatrick, 1986). Field studies demonstrated inhibitory effect of *Eucalyptus* plantation on many agricultural crops up to a distance of 5-7 meter (Basu *et al.*,1987; Kohli

et al.,1990; Parihar,1994; Tauro and Narwal, 1992).

Acacia : The influence of single row plantation of *Acacia nilotica* on the growth and yield of associated *Triticum aestivum* under irrigated condition in Haryana, India (Sharma,1992). As the distance from the tree line increase, the growth and yield for wheat crop also improved. The effect on *Triticum aestivum* was more pronounced in plots towards the middle of tree line as compared to plot towards the outer border. A similar study conducted (Casal *et al.*, 1985; Dalal *et al.*,1992) under rainfed condition showed complete suppressive effect of *Acacia nilotica* on *Brassica compestris* crop up to a distance of 26 m from the tree line. The crop germination was satisfactory but the crop died later. As the distance increased, the adverse effect decreased gradually on all growth parameters. Growth of *Gossypium hirsutum*, *Pennisetum typhoides* and *Brassica compestris* was poor near the trees up to 5m and was markedly inhibited up to 30 m. Besides, moisture nutrients and light, allelopathy may be one of the reasons for poor crop performance under *Acacia nilotica.*

Prosopis : In natural conditions, some grasses such as *Panicum maximum* grow luxuriantly under *Prosopis cineraria* canopy cover, with significant higher productivity over open areas grown crop (Srivastava, and Hegarthi, 1991). Like wise richer vegetation and better crop growth under *Prosopis cineraria* have been reported (Arya *et al.*, 1991). In semi-arid region of India soil nitrogen, organic carbon and grasses yield declined significantly with increasing distance from *Prosopis cineraria.* However, *Prosopis juliflora* had a negative effect on associated vegetation (Pandya,1994), due to the presence of germination and growth inhibitors in leaf litter. Dalal *et al.*, (1992), compared the

suppression effect of arid zone trees on plant stand and growth of winter crops and found that *Prosopis cineraria* did not affect the germination, growth and plant population of *Cicer aretinum*.

Populus : *Populus deltoides* is an important multipurpose tree species suitable for agroforestry. It is reported to exhibit allelopathic effect, through inhibition of seed germination, root and shoot growth of tested species in bioassays with leaf leachate/extract, thus reducing crop yield in agroforestry systems. However, in the initial stages, *Populus deltoides* aqueous extracts stimulated the germination rates in *Triticum aestivum*, *Lens esculanta* and *Cicer aretinum*. It also accelerated the shoot growth of *Lens esculanta* and root branching in *Cicer aretinum* (Nandal *et al.*,1992; Bisla *et al.*, 1992).

Leucaena leucocephala : Allelopathic influence of *Leucaena* on *Sorghum vulgare, Vicia faba* and *Helianthus annus* leaves have been reported by Suresh and Rai (1987). Seed germination, root length and dry matter production were adversely affected by both *Leucaena* top soil and aqueous extracts of leaves of *Leucaena* (Koul,1990). However, no significant effect of *Leucaena* soil and decomposed leaf extract could be was detected on the germination of *Oryza sativa.* This finding contradicts the result of previous laboratory study (Chou and Kuo, 1986), where extract of fresh leaves of *Leucaena* inhibited *Oryza sativa* seed germination. Perhaps, leaf decomposition and leaching of toxins from the soil due to rain reduced the phytotoxicity (Koul, 1990).

Chouhan *et al.*, (1992), reported that *Leucaena* had the least allelopathic effect on dry matter production of all the associated grasses *viz.Sehima nervosum, Heteropogon contortus, Apluda mutica, Cenchrus ciliaris* and *Cenchrus setigerus* among *Leucaena leucocephala,*

Eucalyptus tereticornis, Prosopis juliflora, Acacia auriculiformis, Pithoclobium dulce and Cassia siamea,. Singh (1983), reported significant increase in the productivity of *Cajanus cajan, Sesamum indicum, Ricinus communis* and *Sorghum vulgare* under *Leucaena* trees. The stimulatory effect of second and third leaf extract of *Leucaena leucocephala* has been reported to boost the forage yield of *Zea mays, Sorghum bicolor* and *Pennisetum trifolium* and *Avena sativa* under field conditions (Gill and Patil, 1981; Gill *et al.*, 1982; Parihar,1990; 1994). The allelopathic potentials of many other trees of agroforestry system viz. *Acacia auriculiformis, Casuarina equisetifolia, Tectona grandis, Ficus* sp. have also been reported (Bhatt and Todaria, 1990; Jadhav and Gayanar,1995; Melkania,1992; Parihar,1994).

Objectives

The perusal of the present available literature does not exhibit a clearcut elucidation of allelopathic potential of *Leucaena leucocephala.* Therefore the prime aim of the proposed study is to elucidate the spectrum of allelopathic potential of *Leucaena leucocephala* with the following objectives:

1. To assess the influence of fresh leaf extract on seed germination, seedling growth and seedling vigour in laboratory.
2. To obtain information pertaining to the effect of soil beneath the old (5-6 years) plantation of *Leucaena leucocephala* on the seed germination and seedling growth in pot culture.
3. To determine the influence of mimosine on seed germination seedling growth and early growth of plant (upto 3 months) at weekly intervals.

4. Influence of *Leucaena leucocephala* on the intercrops in agroforestry situation with special reference to the following parameters :

i) Growth parameters of *Leucaena* and intercrops *viz.* height, number of branches, area of leaf and dry matter production.

ii) Ecophysiological parameters such as light, temperature, relative humidity and rate of transpiration.

iii) Plant analysis to determine changes in N, P and K levels, protein, and phenols.

iv) Soil analysis to elucidate changes that occur during the experimentation.

v) Analysis of leaf litter to collect information on mimosine and phenol levels.

5. To estimate the mimosine and phenol contents at different growth stages of plant and leaves.

6. Statistical analysis of the data and determination of significance.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Although the impact of allelopathy in agriculture and forestry was recognised since 300 B.C. when, Theophrastus reported, the allelopathic effect in *Cicer aretinum*, thereafter, this vistas of science remained under dormancy till 20th century. Most of the allelopathic research was conducted during 20th century. According to Rice (1984), considerable research work on allelopathy has been done in developed countries. In India very sparse information is available on this subject. Contrary to this, it is a major field of research in developed countries and has been implicated in most of the problems in agriculture, horticulture and forestry. The proper exploitation of allelopathy may reduce the dependence on herbicides, fungicides, nematicides and/or insecticides. Further, allelopathy has been reported to reduce contamination of environment, diminish hazards of autotoxicity and soil sickness in agriculture, forestry and agroforestry (Waller, 1987). It is evident from the available literature that considerable work has been done on allelopathy with special reference to agriculture, horticulture, forestry and agroforestry in many countries including India. The aforesaid research work conducted so far has nicely been reviewed by Rice (1984) and Narwal (1994; 1996). Agroforestry is an efficient land use system where trees/shrubs are grown with arable crops seeking positive interactions for enhancing the productivity on a sustainable basis. In agroforestry systems woody component is a dominant factor which affects the understorey vegetation through two ways, firstly, it competes for water, light and nutrients besides the shading effect and secondly, by releasing gases/chemicals into environment and soil through roots and leaves. These chemicals may inhibit or stimulate the growth of the

understorey vegetation. This review will be restricted to the allelopathic potential of those tree species which are grown in combination with arable crops in various agroforestry systems.

Eucalyptus

Although, there are many early reports on die back of *Eucalyptus* in natural forests, the first suggestion that allelopathy may be the factor in *Eucalyptus* ecology originated from Jarrot and Petrie (1929), studies. Mount (1964), gave the explanation which did not include any suggestion for allelopathic mechanism, but Mount (1968), proposed a more general theme that plant during metabolism reduce waste by products which must be eliminated, it can be achieved through removal of litter which releases volatile and water soluble metabolite. The waste theory of allelopathy is certainly not new and dates back to 18th century but it could not attract much attention till the beginning of 20th century

Recently, the allelopathic potential of various plants, parts of *Eucalyptus* found commonly either as natives or as introductions, including *E. globulus sp. bicostata, E. maculata, E. macrorhynca, E. elata, E. radiata, E. rosii, E. rubida, E. mannifera, E. blakelyi, E. polyanthemos* and *E. melliodora* were studied in some detail (May, 1989; May and Ash, 1990). The major source of allelochemicals was found to be stem flow, specially in *E. globulus* and *E. macrorhynca* and this may be significant in explaining suppression zones near trees. May and Ash (1990), observed differences in soil response to allelochemicals as *Eucalyptus* soil treated with leachate showed 24% germination of *Lolium* seeds, whereas, adjacent grassland soil showed only 5% germination. There was an estimated 8% decline per day for allelopathic activity of leachates. The production of allelochemicals may be greater

in wet climates, allelopathy may be of greater significance in drier climates where, competition for moisture and the concentration of allelochemicals may cause suppression.

Mature fronds were not inhibitory and the degree of phytoxicity of the young fronds varied according to the time since the last rainfall. Tolhurst and Turvey (1992), also investigated the effect of *Pteridium esculentum* in open forests of *E. obliqua, E. radiata* and *E. rubida* in west central Victoria. They found that frond leachates had no effect on *Eucalyptus* seed germination probably because they were working with senescing fronds and then there was high rainfall.

Aqueous extract of the foliage showed low allelopathic activity whereas, the beetle frass severely inhibited germination of *B. compestris* seed in bioassay. Thus the beetles provides a mean of release and transport of phytotoxin from the foliage of *E. globulus*. Trenbath and Fox (1976; 1977), proposed the novel idea that *E. globulus* may chemically influence the growth of plants beneath the canopy through insect vector. They observed that bare zones commonly develop under certain individual mature trees of *E. globulus*. In subsequent trials Trenbath and Silander(1978), investigated the phytotoxicity of Frass from *Chrysomelid beetle* on *Prosopis atmaria*, feeding on leaves of *E. biocostata*. Natural rates of frass fall are estimated to range from 20 to 2500 kg/ha/yr (Silander *et al.*, 1983) and the monitoring of one tree of *E. globulus* revealed that frass fall averaged 328 kg/ha over six months. Trenbath and Slender (1978), estimated that for each gram of *Eucalyptus* foliage produced, 0.4 g becomes insect frass, 0.4 g eventually becomes litter and 0.2 g is metabolised by insects. They observed that in the field, *Trifolium repens* and the *Themeda triandra* were rarely found in the bare

zone beneath *E. globulus*. Ohmart (1985), criticised numerous aspects of the work of Trenbath and his coworkers, according to them the rate of frass fall was about 100 - 150 kg/ha/yr. Silander *et al.* (1985), answered the criticism of Ohmart and pointed out the inhibition was demonstrated even with a frass doses equivalent to 40 kg/ha. Deshwal and Nandal (1996), reported that leaf litter of Eucalyptus reduced the growth of *Sorghum bicolor, Vicia faba, Pennisetum typhyoides, Cymamopsis tetragonoloba*. The aqueous leachate of *Eucalyptus* leaves inhibit the seed germination, growth, chlorophyll and protein contents of *O. sativa* (Padhy and Khan, 1996).

Inhibition of Nitrification

American ecologist Rice and Pancholy (1972), stated that nitrification progressively inhibited several stages of succession. The key to this theory was the notion that nitrate is leached from soils, ammonium is attracted to clay micelles and ecosystem should have mechanism to conserve nitrogen and hence, promote plant nitrogen acquisition through ammonium uptake, but result did not support this theory (Adams and Attiwill, 1986). A number of investigators have reported that nitrification was suppressed (Florence and Crocker, 1962) and nitrifier were often scarce in soils dominated by *Eucalyptus* (Jones and Richards, 1977; Hopmans *et al.*, 1980; Adam and Attiwill, 1986). The study concluded that nitrification actually increase overall with site is since disturbance and nitrogen mineralization was related primarily to site fertility. Ellis and Pennington (1989), investigated nitrification in soils increased with the age of *Eucalyptus*. To elucidate the cause of seedling mortality in forests of *Eucalyptus* Adams and Attiwill (1982; 1986), concluded that the rate of nitrification was controlled by the rate

of mineralisation and was linked to the C:N ratio and that there was no evidence to support the theory proposed by Rice and Pancholy (1972). This was in agreement with the results of *Eucalyptus* grown as an exotic (Vargues, 1954). Dyck *et al.*, (1983), reported that *E. satigna* foliage leachates contained inhibitors to nitrifers in New Zealand, contrary to a claim of no allelopathic activity by Reid and Wilson, (1985).

In contrast to the above situation, in Australia where introduced species are growing beneath *Eucalyptus* are well known to affect the growth of understorey species. Rabotonov (1977; 1982), proposed that allelopathy should be of greatest significance in plant communities comprising new plant introductions. Allelopathy in native vegetation is better seen as a subtle filter which govern the species composition of the community. Direct allelopathy, in which *Eucalyptus* inhibits other species in order to promote their own chances of survival as a major factor in Australian *Eucalyptus* forest. The study linked to allelopathy in Australian *Eucalyptus* involved the apparent inhibition of seedling growth or autotoxicity and it is difficult to justify from an evolutionary point of view (Newman, 1978; Wilson and Agnew, 1992).

Allelochemicals are present in the environment, they can't be directly related to vegetation patterning but have some effect. The ecology of *Eucalyptus* in Australia is intimately connected to fire, which changes soils conditions and fire must be influenced by the allelochemicals of the plants. The copious amounts of *Eucalyptus* litter with its high C:N ratio, accompanied by various allelochemicals influence the balance of soil microorganism, including ammonifers and nitrifers, mycorrhizae and pathogens which ultimately affect the status and over all growth of Eucalyptus forest. The allelopathic relationship

of species in Australian forest and woodlands are complex and reflect a extensive history of species co evolutionary interaction.

Igboanugo (1986; 1987; 1988), reported adverse effect of *E. camaldulensis, E. grandiflora* and *E. citriodora* on the growth attributes of *Abelmoschus esculantus, Triticum aestivum, Vicia faba* and *Zea mays* sown in the alleys of 20 years old plantation. Dhillon *et al.*, (1979; 1982), have reported inhibitory effects of 10-20m tall *E. tereticornis* plantation on the yield of *T. aestivum, Horideum vulgare, Solanum tuberosum* and *O.sativa* with distance of 1 to 33 m from *Eucalyptus* rows planted east-west and south-north direction. Narwal and Sharmah (1992), observed the effect of two rows of 5-7 years old trees of *E. tereticornis* trees on *P. typhyoides, S.vulgare, Z. mays, Cajanus cajun, Crotelaria juncea, Sesbania sesban* and *Ricinus communis*.

The top soil taken from the plantation of *E. camaldulensis E. grandis* and *E. tereticornis* inhibited the germination of *V. faba, C. cajan, Macrotyluma uniforum* and *Dolichos lablab* (Shivanna *et al.*, 1992). However, Melkania (1984), observed no significant effect of *E. tereticornis* soil leachates and rain drip on *the* seed germination of *T. aestivum*. Lisanewor and Michelson (1993), suggested that the planting of *E. camaldulensis* in integrated land use systems should be minimised, whereas, the use of *E. globulus* was less environmentally damaging likewise Rao and Reddy (1984), observed a stimulatory effect on yield of *T. aestivum, P. typhoides* and *C. sativum.*

Contrary to the above, toxic influence of *E. tereticornis*, leaf leachate on the germination and growth of *T. aestivum* and *B. compestris* have also been reported earlier (Sharma *et al.*, 1967; Puri,1992; Puri and Khara, 1991). The order of toxicity was brown

leaves >green leaves> decayed leaves > stem. *E. tereticornis* allelochemicals have also been reported to affect the germination and seedling growth adversely in *T. aestivum, Z. mays*, *Pisum sativum, B. compestris*, *L. esculanta* (Joshi and Prakash, 1992). *Eleusine coracana*, *Vigna radiata*, *M. uniforum* and *coriander sativum*, being most sensitive crops (Bhaskar *et al.*, 1992; Joshi and Prakash, 1992). Recently, Malik and Surendran (1998), reported that leaf extract of *Eucalyptus* reduced seed germination and seedling growth of *Phaseolus lunatus*, *Z. mays* and *S. tuberosum.*

E. tereticornis caused 64.8 and 30.7 % reduction in seed yield of *Glycine max* at 1 and 5 m distance away from bole, respectively. Similarly, this tree species reduced the yield of *Carthamus tinctorius* at 75.1 and 53.3 % at the distance of 1 and 5 m distance away from bole, respectively, (Solanki *et al.*, 1999).

Populus

Aqueous extract of *Populus balsamifera* or its leaf litter inhibited seed germination of *Alnus spp*. The inhibitory effect was more pronounced on radicle growth in young seedlings, while shoot growth was drastically affected in older seedlings.

Bioassay studies revealed that the extract of both fresh and partially decomposed residues of *P. deltoides* had an adverse effect on the germination of *B. compestris* and *P. sativum* than on *T. aestivum* and *Z. mays* (Joshi and Prakash,1992). Similar ill effects of *P. deltoides* leaf extracts on the germination and growth of *T. aestivum, S. bicolor, L. esculanta, C. aretinum, B. compestris,*

Raphanus sativa, Solanum melongena, Trigonella foenumgraecum and *Allium cepa* have been reported. However, in the initial stages aqueous leaf extracts of Poplar stimulated the germination in *T. aestivum, L. esculanta* and *C. aretinum*. It also accelerated the shoot growth of *L. esculanta* and root branching in *C. aretinum* (Bisla *et al.*, 1992; Carley and Watson, 1967).

However, *P. deltoides* exhibited adverse effect on crops and their economic yield in the subsequent years due to function of more leaves and huge litter (Khattak and Sheikh, 1980;1981). Melkania (1984), has also reported an inhibitory effect of *P. deltoides* leaf, soil, leachates and rain drip on seed germination and radicle growth in *T. aestivum* and *C. aretinum*. Freshly fallen leaf litter of *P. trimuloides* have catechol and benzoic acid which inhibit the seedling growth of herbaceous species (Younger *et al.*, 1980). Its bark contains pyrocatecol, an inhibitor of pathogenic fungus (Hubbes,1962; 1966). *P. deltoides* had no significant adverse effect either on growth or yield of *T. aestivum* and other tested crops in the first three years. Leaf leachate of *P. deltoides* also reduced the germination of *O. sativa*. Aqueous leachate extract of *P. deltoides* retarded the germination and growth of *phaseolus aureus* (Kohli *et al.*, 1997).

Gill (1995), reported production of 1.5t/acre/yr of *T. aestivum* or its equivalent to oilseed crops, flowers, forages etc. when grown in association with 11.5 year old *Populus* plants in a farmers field at Haryana. About 80-100 plants of *Litchi chinensis* and *Mangifera*

indica were grown with 100 poplar plants per acre and *Curcuma domestica* was grown as intercrop, the net income and yield was more than the traditional systems.

Prosopis

There are three species of genus *Prosopis* namely, *P. cineraria, P. juliflora* and *P. glandulosa.* These species are reported to have allelopathic potential. Singh and Lal (1969), reported that soil under *P. cineraria* had higher content of organic matter, total nitrogen, available phosphorus and soluble calcium as compared to open field conditions. High organic matter content in the soil may be attributed to leaf fall and its faster mineralization due to favourable moisture conditions that exists under *P.cineraria* canopy (Gupta,1975). Shankar and Saxena (1976), reported that *P. cineraria* had a boosting effect on the herbage yield, growth and botanical composition of natural pastures. The aqueous extract of *P. glandulosa* inhibited seed germination, root and shoot elongation in *T. aestivum*. The inhibitory effect was found directly proportional to the concentration of extract (Alam and Azami, 1989; Azami and Alam, 1989). Similar reduction was observed due to root exudates in *Z. mays* and *T. aestivum* (Nimbal *et al.*, 1990), contrary to the above, root exudates have been reported to stimulate growth (Nimbal *et al.*, 1990) in *Arachis hypogea*.Root exudates also inhibited germination and radicle growth of *S. bicolor, T. aestivum, Z. mays* and *Carthamus tinctorius*. A reduction in radicle growth

was observed in *C. aretinum* and *V. faba* but not in germination, while, the reverse was true for *A. hypogea* (Nimbal *et al.*, 1990).

In natural conditions, some grasses such as *Panicum maximum* grow luxuriously under *P. cineraria* canopy cover, with significantly higher productivity over open areas (Srivastava and Hegarthi, 1991). Likewise richer vegetation and better crop growth under *P. cineraria* been reported (Arya *et al.*, 1991). Dalal *et al.*, (1992), found that *P. cineraria* did not affect the germination, growth and plant population of *C. aretinum*. Chouhan *et al.*, (1992), studied the allelopathic effect of *P. juliflora* on associated grasses under silvipastoral system and reported that the early stages of tree growth did not show its effect, however, at later stage it exerted maximum allelopathic effect. *P. glandulosa* has an inhibitory effect on the shoot and root length of various *T. aestivum* cultivars and the inhibition increased with increasing concentration of extract. In semi-arid region of India, soil nitrogen, organic carbon and grasses yield declined significantly with increasing distance from *P. cineraria*. However, *P. juliflora* had negative effect on associated vegetation (Pandya,1994) due to the presence of germination and growth inhibitors in leaf litter.

Acacia

Aqueous extract of bark and leaves of six years old *Acacia nilotica* trees significantly inhibited seed germination, radicle and plumule growth of *S. bicolor, Gossypium hirsutum, Abelmaschus esculantus, Capsicum annuum, Lycopersicon esculentum* and *Helianthus annus*. The inhibition in germination due to bark extract was more profound than that of leaf extract (Bhumibhamon *et al.*, 1980).

Sundermurti and Kalra (1991), studied the allelopathic effects of *A. tortilis* plantation at Jodhpur, Rajasthan and found that the properties of soil beneath *A. tortilis* and *P. cineraria* did not differ significantly in their physico-chemical constituents. This indicate that the growth of understorey plant is inhibited not due to changes in soil mineral status but because of some chemical interference which may be attributed to allelopathy. Bhatt and Todaria (1992), reported that the phytotoxins, mainly the tannin were present in the extract. The leaf leachate of *A. nilotica* reduced germination, root, shoot length and seedling vigour of *B. compestris*, *L. esculanta*, *P. sativum* and *T. aestivum* and its underneath soils and bark extract suppressed germination of *C. tetragonoloba* and *P. tryphoides*.

The soil extracts beneath the *A. tortilis* exhibited inhibitory effect on germination and seedling growth of *P. tryphoides, C. tetragonoloba* and *Seasamum indicum,* was most adversely affected. In another study Sundermurti *et al.*, (1992), stated that the stem, leaf litter and soil leachates of *A. tortilis* exhibited inhibitory as well as promotory effects on all the legume test crops, namely, *C. tetragonoloba*, *V. radiata* and *Phaseolus vulgaris*. Leaf leachates of *A. auriculiformis* decrease the percent germination, plumule and radicle length and dry matter in *O. sativa* and *V. faba*. Length and dry matter accumulation in the radicle were more affected in *O. sativa* than *V. faba* (Jadhav and Gayner, 1992).

The influence of single row plantation of *A. nilotica* on the growth and yield of *T. aestivum* under irrigated conditions in Haryana was studied by Sharma (1992), and observed that tree line affected the plant height, number of tillers, ear length, grain number and grain yield up to a distance of 4 m from the tree line. As the distance from the tree line

increases , the growth and yield of *T.aestivum* also improved. The effect on *T. aestivum* was more pronounced in plots towards the middle of the tree line as compared to plot towards the outer border. A similar study conducted (Casal *et al.*, 1985; Dalal *et al.*, 1992) under rainfed conditions reported inhibitory effect of *A. nilotica* on *B. compestris* up to a distance of 26 m from the tree line. The seed germination was unaffected but the seedling died later. As the distance increased, the adverse effect decreased gradually on growth parameters. The plant stand was reduced to 71% and 28-30m and 57% over the control at 30-32m. The reduction in plant height, number of branches, leaves and siliqua per plant was very significant up to 26 m distance, growth of *G. hirsutum, P. typhoides* and *B. compestris* was poor near the trees up to 5 m and was markedly inhibited up to 30 m. Besides, moisture and light, allelopathy may be one of the reason for poor crop performance under *A. nilotica*. Dalal *et al.*,(1992), stated that *A. nilotica* inhibit the height, shoot number and yield of *T. aestivum, B. compestris* and *G. hirsutum. A. nilotica* reduced the shoot biomass of *T. aestivum, B. compestris* and *C. arietinum*(Puri *et al.*, 1992).

Saxena *et al.*,(1995), reported that *A. tortilis* and *A. nilotica* inhibited the growth of *P. typhoides, C. arietinum* and *B. compestris* under their canopies. Saxena and Sharma (1996), reported that leaf extract of *A. tortilis* inhibited the germination and root shoot length of the seedling of *P. typhoides*. Fresh leaf extract of *A. nilotica* stimulate the germination per cent, root and shoot length over control in *Glycine max* at 5, 10, 20% (Tripathi *et al.*, 1998).Studies conducted at CCS Haryana Agriculture University, Hisar revealed that order of harmful effects of *A. nilotica* leachates on germination and growth of *T.aestivum*,

C.aretinum and *B. compestris* was pod > mixed > flower > leaf > root (Solanki *et al.*, 1999).*A. nilotica* caused 72.6 and 29.5 % reduction in seed yield of *Glycine max* at 1 and 5 meters distance away from bole, respectively. Similarly, it reduced the yield of *C. tinctorius* to 82.9 and 68.8 % at the distance of 1 and 5 meters away from bole, respectively. Further, studies revealed that the yield of *O. sativa* increased with increase in hedge row distance of *A. auricliformis* (Solanki *et al.*, 1999).

Bamboo

The aqueous leaf extract inhibited seed germination and growth as well as decreased total chlorophyl and protein content in *A. hypogea* (Eyini *et al.*, 1989). The reduction in growth attributes was found proportional to concentration of the leaf extract (Eyini *et al.*, 1989). Many other species of bamboo have been reported to suppress seed germination in *O. sativa, Triticale* and *Lactuca sativa* (Chou, 1983; Narwal, 1996). Recently, bamboo has been found to have allelopathic effects on crops (Narwal, 1996). The leaf and root extracts of *Bambusa arundinacea* reduced the shoot, root length, leaf area and total chlorophyll contents of *O. sativa* (Panneereselvam *et al.*, 1998). Bamboo is a rich source of phenolic acids. Six phenolic acids have been isolated from bamboo leaves, reported to cause allelopathic effects. According to Tasi and Young (1993), soil near the bamboo rhizomes contain higher quantity of allelochemicals namely, *P-hydrobenzoic, trans-phydroxy cinnamic, B-(m-hydroxyphenyl), propionic, transferulic, 3-4 dimethoxybenzoic and 2-6-dihydroxybenzoic acids and 4-hydroxy-3-ethoxybenzaldehyde.* However, there is need for extensive research to know which of the phenolic acid affected seed germination and

subsequent growth of seedling. Generally bamboo reduces the growth of conifers such as *Pinus* and *Cryptomeria.* The reduction in growth of conifers resulted in the decline in their productivity. Reduction in crop yield of *Phaseolus radiatus* had been reported in bamboo based agroforestry systems (Bisaria *et al.*, 1998).

Juglans nigra

The *Juglans nigra* plants were injurious to plants in its vicinity. Most of the herbs did not grow under the *J. nigra* tree was due to the presence of juglans (5-hydroxy-1, 4 nepthaquinone) in the leaves and fruits. Rain washed chemicals got oxidised to its toxic form oxyjulone in the soil Stickney and Hoy (1981). *S. tuberosum* and *Lycopersicon esculantum* plants growth near black *J. nigra* could not grow due to wilting (Cook,1921). Massey(1925), found that *alfalfa* and *L. esculantum* plants wilted and died whenever their roots came into close contact with *J. nigra* tree roots. The effect was so dramatic that he could trace the extent of the *J. nigra* tree roots without removing the soil and just observing the development of wilting in tested plants. There was no specific relationship between the region of maximum concentration of *J. nigra* roots and wilting of tomatoes and the plant responses were similar to that of drought. Apparently, there was significant soil sickness and the roots of the affected plants had to be in close contact with *J. nigra* tree roots. When pieces of bark from *J. nigra* roots were placed in a water culture of *L. esculantum* plants, the plants wilted and their roots turned brown within 48 hrs. In addition to bark from *J. nigra* roots to the soil in which tomato plants were grown inhibited the growth of the later. It was suggested that *J. nigra* produced some substance which

might had the toxic constituents, which remains to be isolated and identified. Davis (1928), isolated toxic substance from the hulls and roots of *J. nigra* was juglans. The compound proved as a powerful toxic agent when injected into the stems of *L. esculantum* and *alfalfa* plants. Growing of *L. esculantum* at high density decreased the phytotoxicity of *J. nigra* perhaps due to availability of toxin at lower concentration (Weidenhamer *et al.*, 1989).

Soil beneath the plantation of *J. nigra* did not differ in physico-chemical properties (Husain *et al.*, 1991). However, the height, shoot fresh and dry weights decreased in *S. tuberosum, Z. mays* and *P. sativum* due to *J. nigra* trees as compared to control. Bioassay analysis of aqueous extracts of shoot litter, natural rain leachates and soil collected from beneath *J. nigra* in bioassays significantly reduced germination, early seedling growth, fresh and dry weight of *Z. mays*, *B. rapa* and *D. lablab.* ferulic, p-coumaric, caffeic, vanillic, p-hydroxybenzoic, chlorogenic and gallic acid were identified as the possible allelopathic substances in the aqueous extracts and rain leachates of the *J. nigra* trees. These findings suggested that the poor growth of crops was due to allelopathic effect of walnut trees.

Leucaena leucocephala

Subabul (*Leucaena leucocephala*) a fast growing nitrogen fixing tree (NFT) is a well known fodder yielding tree. *L. leucocephala* is planted in agrisilvicultural, agrisilvi-horticultural, silvipastoral and silvicultural systems. However, it's allelopathic properties have recently been elucidated (Kuo *et al.*, 1982). Chou (1983), reported that the aqueous extract of leaves stimulated the seed germination and seedling

growth of *O. sativa.* Suresh and Rai (1987), observed allelopathic influence of *L. leucocephala* on *S. bicolor*, *V. faba* and *H. annus*. Seed germination, root length and dry matter production were adversely affected by the aqueous leaf extract of *L. leucocephala.* Koul(1990), reported no significant effect of *L. leucocephala* soil and decomposed leaves extract on the germination of *O. sativa*. This finding contradict the previous study where extract from fresh leaf of *L. leucocephala* negatively affected *O. sativa* seed germination (Koul and Singh,1989). Leaf extract of *L. leucocephala* inhibit the germination and growth of *T. aestivum*, *Z. mays*, *Pisum sativum* and *B. compestris* (Joshi and Prakash,1992). Rao*et al.*,(1994), stated that the inhibition of germination of *T. aestivum* and *O. sativa* was directly proportional to the concentration of leaf extract of *L. leucocephala*. Velu *et al.*,(1996), reported the aqueous leaf extract of *L. leucocephala* decrease the germination and seedling growth of *G. max, Vigna mungo* and *A. hypogaea.*

It has been reported that among *L. leucocephala, E. tereticornis, Prosopis juliflora, Acacia auriculiformis, Pithoclobium dulce* and *Cassia siamea*, *Leucaena* had the least allelopathic effect on dry matter production of all the associated grasses viz. *Sehima nervosum, Heteropogon contortus, Apluda mutica, Cenchrus ciliaris and C. setigerus* (Chouhan *et al.*, 1992). The phytotoxicity of *Leucaena* leaf extract on *O. sativa* (Chaturvedi and Jha, 1992) and *G. max*, *G. hirsutum* and *V. mungo* (Dharamraj, 1998) was evaluated. Among three successive leaf extracts tested, the first extract showed an inhibitory effect, while third extract exhibited a stimulatory effect on the radicle growth of *O. sativa*, *G. max* and *V. mungo*. The stimulatory effect of second and third

leaf extract of *L. leucocephala* has been reported to boost the forage yield of *Z. mays, S. bicolor, Pennisetum trifolium* and *A. sativa* (Gill and Patil, 1981; Gill *et al.*, 1992; Parihar, 1990; 1994).

Leucaena leaves and other plant parts contain following ten phytotoxins

1. Mimosine,
2. Quercetin,
3. Gallic acid ,
4. Protocatechuic acid,
5. p-oH Benzoic acid
6. p-oH Phenylacetic acid,
7. Vanilliid,
8. Ferulic acid,
9. Caffeic acid,
10. p- Coumaric acid.

The leaf leachates suppressed the growth of *A. confusa, C. clauca* and *A. formosana* and decreased the population density of understorey crops due to allelopathic effect (Chou and Kuo, 1986).It's rhizosphere soil, field soil mulched with leaves or their extracts depressed the germination, root length and dry matter production in *S. bicolor*, *V. faba* and *H. annus* compared with control (Swaminathan *et al.*, 1989). The effect of second extract was inconsistent. The allelopathic effect of leaf leachate of *L. leucocephala* reduced the seed germination of *O. sativa* (Koul *et al.*, 1991) similar phytotoxic effect of *L. leucocephala* on seed germination of *L. sativa* and *Lolium perenne* (Chou, 1989). Leaf litter of *L. leucocephala* reduced the growth of *V. faba*, *S. bicolor* and *C. tetragonoloba* (Deshwal and Nandal, 1996).

Mimosine, a non- protein amino acid which is present in leaves, flowers, pods and seeds of *L. leucocephala* has been reported to cause toxic effect on many plants (Hegarthi *et al.*, 1976; Jones, 1981; Reis *et al.*, 1975). Mimosine inhibited the germination of *V. radiata*, whereas the growth of understorey *Leucaena* seedlings was not affected under mature

Leucaena trees, perhaps, *Leucaena* has a detoxification mechanism that degrades mimosine in to, 3-4 dihydroxy pyridine and then converts into a non- toxic metabolite (Smith and Fowden,1966). Kuo *et al.*, (1983) observed a significant inhibition of radicle growth in *L. sativa* and *O. sativa* at a mimosine concentrations of 10 and 20 ppm, respectively. Tawata and Hongo (1987), tested mimosine at various concentrations, for its allelopathic activities against *O. sativa*, *R. sativus*, *B. rapa*, *P.vulgaris*, *Daucus carota* and *Bidens pilosa*. Radicle growth of all species was inhibited at 10 ppm concentration, while growth of *O. sativa R. sativus*, *B. rapa*, *P.vulgaris* was promoted at 1ppm. *P.vulgaris*, *D. carota* and *Bidens pilosa* were less sensitive to mimosine than the other species. Mimosine concentrations from 0.25 to 1.5 um inhibited germination, radicle and plumule length of *O. sativa* and *V. radiata* Mimosine had an inhibitory effect on the germination and radicle growth of *L. sativa*, *O. sativa* and *Lolium perenne* (Wilson and Bell 1979; Kuo et al., 1983; Chou and Kuo,1986). Singh(1983), reported significant increase in the productivity of *C. cajan, S. indicum, R. communis* and *S. bicolor* under *Leucaena* trees.Yet, limited information is available on it's allelopathic effects. Pathak (1988), reported 40% increase in *Avina sativa* yield under the *L. leucocephala* trees. It has been reported that the yield of *Z. mays* improved under hedgerow inter cropping with *L. leucocephala* yield of *Z. mays* was highest when the hedgerow was cut to 10 cm (Macklin *et al.*, 1988). If the hedgerow was not pruned, *Z. mays* yield were severely depressed (Field and Matan, 1990). Mimosine inhibited the germination of *V. radiata*. *L. leucocephala* reduced the yield of *T. aestivum* and *V. radiata* in agrisilviculture system just 3rd year onwards (Deb Roy and Gill,1991). The reduction was more profound in the subsequent years

(Bisaria *et al.*, 1997). Korwar and Radder (1991), evaluated the potential of alley cropping *S. bicolor* between *Leucaena* hedgerows. Alley cropping decreased *S. bicolor* yields by 28 -45 percent when all *Leucaena* pruning were removed from the system and by 21-24 percent when on average 1.92 t/ha pruning were applied to the soil annually. Although, alley cropping increased organic carbon by 21 per cent and available nitrogen 19 per cent, it did not result in increased crop yields due to competition for water. Chaturvedi and Jha (1994), evaluated the influence of *L. leucocephala* on alley cropped *T. aestivum, Z. mays* and *V. radiata* grain yields. Reduction to the tune of 55 and 47 % in grain yield of *Z. mays* and *T. aestivum,* respectively were recorded in the lines adjacent to hedgerows in comparison to mid lines. The yield increased with the application of 15 t/ha dry *Leucaena* leaf pruning. Yield of *S. bicolor* decreases in between the decomposition of mulching of *L. leucocephala*, but after complete decomposition it increased 117% over control (Wiegard and Jutzi, 1996). Yield of *T. aestivum* increased up to 25% over control by mulching at the rate of 2.25 t/ha (Sharma *et al.*, 1997). *L. leucocephala* not only reduced the yield of *V. radiata* but also affected the growth and yield of *Emblica officinalis* in agrihortisilvicultural system under rainfed conditions (Bisaria *et al.*, 1998).

In *L. leucocephala* based alley cropping system, green leaf fodder production ranged from 1.5 to 2.87 t/ha with maximum yield in eight meter alley and lowest in 4 meter alley treatment. The *G. max* yield parameter showed significant difference between different alley treatments. The highest mean yield was recorded in sole crop (22.13 q/ha) and minimum in 4 meter alley (3.69 q/ha) (Solanki *et al.*, 1999). In Kerala

Leucaena had been found to affect adversely the understorey herbage yield of *Pennisetum purpureum, Teosinate* and *Panicum maximum.*

In addition to the aforesaid tree species there many other trees which had been reported to exhibit allelopathic potential.

Tectona grandis **:** Bumibhamon *et al.*(1980), reported the presence of a phyto-oxide in *Tectona grandis*. The aqueous or alcohol extracts of its fruit mesocarp inhibited the germination of *O. sativa* and pine seeds. On the other hand a stimulatory effect of *T. grandis* leaf leachates was reported on the percentage sprouting rhizomes, sprouting time and growth of *Costus speciosus* grown widely under the shade of trees in West Bengal, India (Konar and Kushari,1989).

The leaf, root and soil aqueous extracts of *T. grandis* increased protein content in seeds and leaves, improved nodulation and increased peroxidase activity, promoted chlorophyll b in leaves while adversely affected plumule length. Leaf and soil extracts promoted germination, shoot length and root length of *G. max,* while decreased carbohydrate. Soil and root extracts promoted radicle length and amino acid while inhibited ascorbic acid in leaves. Hence, leaf, root and soil extracts have promontory effect on *G. max* (Tripathi and Tripathi, 1997)

Shorea robusta **:** *S. robusta* leaf leachates were reported to have a stimulatory effect on the percentage sprouting of rhizomes, sprouting time and growth of *Costus speciosus* grown widely under the shade of trees in West Bengal, India (Konar and Kushari,1989).

Terminalia tomentosa **:** Leaf leachates of *Terminalia tomentosa* had no effect on the germination of *O.sativa* and *V.faba* however, growth and dry matter of plumule and radicle of *O.sativa* were progressively decreased with increasing soaking period, and growth and dry matter of *V.faba*

radicle was increased progressively with increase in soaking period(Gaynar and Jadhav,1992).

Casuarina equisetifolia : It has been reported that the top soil from under *Casuarina equisetifolia* reduced crop germination and growth of *V. radiata, V. mungo, V. faba, C. cajanz* and *G. max* (Srinivasan *et al.*, 1990). Inhibition of seed germination, root length and dry matter production of *S. bicolor, V. faba* and *H. annus* were reported in the top rhizosphere soil of *C. equisetifolia* plantation (Suresh and Rai,1987). Joshi and Parkash (1992), while comparing the allelopathic effect of 10 tree species on *T.aestivum, P.sativum, Z. mays* and *B. compestris* found that fresh litter extract of *Casuarina*. The leaf leachate effect of *C. equisetifolia* significantly decreased the germination, plumule and radicle growth of *O. sativa* and *V. faba* (Jadhav and Gaynar, 1995).

Azadirachta indica : It was observed that the extract of green and senescent leaves of *Azadirachta indica* influences various agricultural crops (Bisla *et al.*,1998). The extracts of green leaves significantly reduced the germination of *P. typhoides, S. bicolor, C. cajan, C. tetragonoloba,* and *V. radiata* by 35.5, 17.4, 18.3, 12.4 and 29.6 %, respectively. The inhibitory effect of senescent leaf extract on germination was greater than green leaf extract. The senescent leaf extract reduced the germination of *P. typhoides, S. bicolor, C. cajan, C. tetragonoloba*, and *V. radiata* by 73.4, 43.4, 81.2, 18.8 and 44.4%, respectively. However, the green leaf extract increased the germination in *V. faba* and *V. mungo* by 4.7 and 20.8 %, respectively. Like germination, both the leaf extracts also adversely affected the seedling growth, however, senescent leaf extract was more inhibitory. Palani and

Dasthagir (1998), studied allelopathic influence of *A. indica* and observed the reduction in growth and yield of *V. faba, S. indicum , and S. bicolor, M. uniflorum* under the rhizosphere soil and mulch .

Dalbergia sissoo : *Dalbergia sissoo* had been found to be suitable timber tree species without affecting the yield of understorey crops up to the age of 11 year under rainfed conditions (Narwal,1996). Arya *et al.*, (1998) studied the effect of *D. sissoo* boundary plantation on the combination of *S. bicolor* + *C. cajan, S. bicolor* + *V. faba, S. bicolor* + *Cenchrus setigerus*. During first two years, there was no effect of *D. sissoo* on associated crop components, but in third year it reduced the grain and stover yield of *S. bicolor.*

Albizia procera : Allelopathic activity of *Albizia procera* was studied on germination and seedling growth of *G. max.* The leaf extract showed stimulatory effect on germination, growth, chlorophyll, protein, carbohydrate and proline content of *G. max.* The leaf extract enhanced germination up to 20 per cent over control The leaves were found rich in phenols, poor in proteins, contained traces of alkaloids and free from flavonoids, steroids and saponins. It is presumed that some part of these active principles might have been present in the leaf extract.

Summary of Review on Allelopathy

Species	Influence	Reference
Cicer aretinum	For the first time impact of allelopathy was recognised	Theophrastus, 300 B.C.
***Eucalyptus* species**		
Eucalyptus species	First suggestion of inhibition by *Eucalyptus*	Jarrot and Petrie, 1929
Eucalyptus species	Suppressed the nitrification	Florence and Crocker, 1962
Eucalyptus species	Die back in trees of *Eucalyptus*	Mount, 1964
E. tereticornis	Toxic influence on the seed germination and seedling growth of *T. aestivum* and *B. compestris*	Sharma *et al.*, 1967
Eucalyptus species	Nitrification inhibition in several stages of succession	Rice and Pancholy, 1972
Eucalyptus species	Reduction in nitrifier in soil	Jones and Richards, 1977
E. globulus	Chemically influence the growth of plants beneath the canopy through insect vector.	Trenbath and Fox, 1976; 1977
E. tereticornis	Inhibitory effect on yield of *T. aestivum, H. vulgare, S. tuberosum* and *O. sativa*	Dhillon *et al.*, 1979;1982

Eucalyptus species	Inhibition of seedling of other species	Robotonov,1977; 1982
Eucalyptus species	Inhibition of seedling of other species	Newman,1978
E. globulus	*T. repens* and the *T. triandra* rarely found beneath in the bare zone.	Trenbath and Silender, 1978
E. bicostata	Phytoxicity of frass from another Chrysomelid beetle and *P. atmaria.*	Trenbath and Silander,1978
Eucalyptus species	Reduction in nitrifier in soil	Hopmans *et al.*, 1980
E. satigna leachate	Inhibition of nitrifier in soil	Dyck *et al.*,1983
E. globulus	Frass fall average 328 kg/ha over six years	Silander *et al.*,1983
E. globulus	Exhibited stimulatory effect on yield of *T. aestivum,P. typhoides* and *C. sativum.*	Rao and Reddy, 1984
E. globulus	Inhibition was demonstrated with frass dose 40 kg/ha	Silander *et al.*,1985
E. satigna	No allelopathic activity	Reid and Wilson, 1985
E. globulus	Rate of frass fall 100-150kg/ha/yr	Ohmart, 1985

E. camaldulensis	Adverse effect on growth attributes of *A. esculantus*	Igboanugo,1986; 1987; 1988
Eucalyptus species	Reduction in nitrifier in soil	Adam and Attiwill, 1986
Eucalyptus species	Stem flow is major source of allelochemical	May,1989
Eucalyptus species	Nitrification in soils increased with the age of tree	Ellis and Pennington,1989
Eucalyptus species	Stem flow as major source of allelochemical	May and Ash,1990
Eucalyptus species	Treated with *Eucalytptus* soil extract germination of *Lolium* seeds inhibited	May and Ash, 1990
E. tereticornis	Toxic influence on the germination and seedling growth of *T. aestivum* and *B. compestris*	Puri and Khara, 1991
E. tereticornis	Toxic influence on the germination and seedling growth of *T. aestivum* and *B. compestris*	Puri,1992

E. tereticornis	Adversely affect the germination and seedling growth of *T. aestivum, Z. Mays P.sativum, B. compestris*, and *L. esculanta*	Joshi and Prakash, 1992
E. tereticornis	*E. coracana, V. radiata, M. uniforum* and *C. sativum* most sensitive crops.	Bhaskar *et al.*, 1 9 9 2;Joshi and Prakash, 1992
E. obliqua, E. radiata,E.rubida	Leachates of leaves had no effect on seed germination in *Eucalyptus*	Tolhurst and Turvey , 1992
Eucalyptus species	Inhibited growth of seedling of other species	Wilson and Agnew, 1992
E. camaldulensis, *E. grandis* and *E. tereticornis*	Inhibit the germination of *V. faba,C. Cajan, M. uniforum* and *D. lablab*	Shivanna *et al.*, 1992
E. globulus	Environmentally less damaging	Lisanewor and Michelson, 1993
Eucalyptus species	Leaf litter reduced the growth of *S.biocolar, V. faba, P. typhoides, C. tetragonoloba*	Deshwal and Nan dal, 1996
Eucalyptus species	Aqueous leachate inhibit the seed germination, growth, Protein contents, Chlorophylls of *O. Sativa*	Padhey and Khan, 1996

Eucalyptus species	Leaf extract reduced the seed germination and seedling growth of *P. lunatus, Z. mays* and *S. tuberosum*	Malik and Sudersan, 1998
E. tereticornis	Reduced the seed yield of *G. max* and *C. tinctorius* up to the distance of 1-5 m from tree base	Solanki *et al.*, 1999
Populus species		
P. trimuloides	Bark contain pathogenic fungus	Hubbes, 1962: 1966
Populus sp.	Stimulate the germination in *T. aestivum*, *L. esculanta, C. aretinum* and accelerated the shoot growth of lentil and root branching in *C. aretinum*	Carley and Watson, 1967; Bisla *et al.*, 1992
P. deltoides	Adverse effect on crop and yield	Khattak and Sheikh, 1980; 1981
P. trimuloides	Inhibit the seedling growth of herbaceous species	Younger *et al.*,1980
P. deltoides	Inhibitory effect on seed germination and radicle growth in *T. aestivum* and *C. aretinum*	Melkania,1984

Populus deltoides	Adverse effect on the germination of *B.compestris*, *P. sativum* than on *T. aestivum* and *Z. mays*	Joshi and Prakash, 1992
Populus species	The production of *T. aestivum* was 1.5t/acre/yr with 11 year old tree	Gill,1995
P. deltoides	Reduced the germination of *P. aureus*	Kohli *et al.*, 1997
Prosopis species		
P. juliflora	Soil under the species contain higher content of organic matter, total nitrogen, phosphorus and soluble calcium	Singh and Lal, 1969
P. cineraria	Soil under the species contain high organic matter content due to leaf fall and its mineralization.	Gupta, 1975
P. juliflora	Boosting effect on the herbage yield, growth and botanical composition of natural pasture	Shankar and Saxena, 1976
P. glandulosa	Inhibit seed germination, root and shoot elongation in *T. aestivum*	Alam and Azmi, 1989; Azmi and Alam, 1989

P. glandulosa	Reduction in *T. aestivum* and *Z. mays* contrary to the above root exudates stimulate the growth in *A. hypogea*	Nimbal *et al.*, 1990
P. glandulosa	inhibitory effect on shoot and root length of *T. aestivum*, root exudates inhibit germination and radicle growth of *S. bicolor*, *Z. mays* and *C. tinctorius*.	Nimbal *et al.*, 1990
P. glandulosa	Reduction in radicle growth in *C. aretinum, V. faba* but not in germination while the reverse in *A. hypogea*	Nimbal *et al.*, 1990
P. cineraria	Productivity of *P. maximum* under canopy significantly higher over open area	Srivastava and Hegarthy,1991
P. cineraria	Richer vegetation and better crop growth under beneath the tree	Arya *et al.*,1991
P. cineraria	Germination and growth of *C. aretinum* not affected	Dalal *et al.*, 1992
P. juliflora	later stage exerted maximum allelopathic effect on associated grasses	Chouhan *et al.*,1992

P. juliflora	Inhibitory effect on associated vegetation	Pandya,1994
Acacia Species		
A. nilotica	Inhibited the germination, radicle and plumule growth of *S. bicolor, G. hirsutum, A. esculantus, C. annuum, L. esculentum* and *H. annus*	Bhumibhamon *et al.*, 1980
A. nilotica	Inhibitory effect on seedling of *B. compestris* up to a distance of 26 m from the tree line	Casal *et al.*, 1985; Dalal *et al.*, 1992
A. tortilis	Soil extract inhibited seed germination and growth of *P. tryphoides, C.tetragonoloba* and *S. indicum*	Sundermurti and Kalra, 1991
A. nilotica	Reduced seed germination, root, shoot length and *seedling vigour of* B. *compestris, L. esculanta, P.sativum* and *T.aestivum*	Bhatt and Todaria, 1992
A. nilotica	Inhibited shoot length and yield of *T. aestivum, B. compestris* and *G. hirudium*	Dalal *et al.*, 1992

A. auriculiformis	Decreased germination, plumule, radicle length and dry matter in *O. sativa* and *V. faba*	Jadhav and Gayner, 1992
A. tortilis	Stem, leaf and soil leachate exhibited inhibitory as well as promotory effect on *C.tetragonoloba* ,*V. Radiata* and *P. vulgaris*	Sundermurti *et al.*, 1992
A. nilotica	Inhibited plant height and grain yield up to a distance of 4 meter from tree line	Sharma,1992
A. nilotica	Reduced shoot biomass of *T. aestivum*, *B. compestris* and *C. aretinum*	Puri *et al.*, 1992
A. tortilis	Inhibited germination and root, shoot length of seedling of *P. typhoides*	Saxena and Sharma,1996
A. nilotica and A. tortilis	Inhibited growth of *T. aestivum, C. aretinum* and *B. compestris*	Saxena *et al.*, 1995
A. nilotica	Stimulated germination, root and shoot length of *G. max.*	Tripathi *et al.*, 1998

A. nilotica	Leachates inhibited germination and seedling growth of *T. aestivum*, *B. compestris* and *C.aretinum*, in the order Pod > flower > leaf > root	Solanki *et al.*,1999
A. nilotica	Reduced yield of *G. max* and *C. tinctorius* near the tree line	Solanki *et al.*,1999
A. auriculiformis	Yield of *O.sativa* increased with increase in hedge row distance	Solanki *et al.*,1999
Bamboo species		
Bamboo species	Suppressed germination in *O. sativa, Tritical* and *L. sativa*	Chou, 1983; Narwal , 1996
Bamboo species	Leaf extract inhibited germination, growth total cholorophyll and Protein content in *A. hypogea*	Eyini *et al.*, 1989
Bamboo species	Soil near bamboo rhizome contain higher quantity of allelochemicals	Tasi and young, 1993

B. arundinacea	Reduced the shoot, root length, leaf area and total chlorophyll content of *O.sativa.*	Panneereselavam *et al.*, 1998
Bamboo species	Reduced yield of *P. radiatus*	Bisaria *et al.*, 1998
Juglans species		
J. nigra	Inhibited growth of *S. tuberosum* and *L. esculantum*	Cook, 1921
J. nigra	Wilted the plants of *L. esculantum*	Massey, 1925
J. nigra	Extracted *Juglans* as toxic substance from roots of *J. nigra*	Davis, 1928
J. nigra	Inhibited growth of plants in its vicinity.	Stickney and Hoy, 1981
J. nigra	Higher density of *L. esculantum* decreased phytotoxicity of Juglans	Weidenhamer *et al.*, 1989
J. nigra	Aqueous extract of shoot litter significantly reduced seedling growth, fresh and dry weight of *Z. mays*, *B. rapa* and *Dolichos lablab*	Husain *et al.*, 1991

Miscellaneous species		
Tectona grandis	Aqueous extract of fruit mesocarp inhibited germination of *O.sativa* and pine seeds	Bumibhamon *et al.*, 1980
T. grandis	Leaf leachates stimulated sprouting and growth of *C. speciosus*	Konar and Kushari, 1989
T. grandis	Leaf, root and soil extracts exhibited promotory effect on growth of *G. max*	Tripathi and Tripathi, 1997
Shorea robusta	Leaf leachate stimulated sprouting and growth of *C. speciosus*	Konar and Kushari, 1989.
Terminalia tomentosa	Leaf leachates inhibited growth and dry matter of *O. sativa* but increased growth of *V.faba*	Gayner and Jadhav, 1992
Casuarina equisetifolia	Reduced seed germination and growth of *V. radiata, V. mungo, V. faba, C. cajan* and *G. max*	Srinivasan *et al.*, 1990
C. equisetifolia	Reduced seed germination, dry matter production of *S. bicolor, V. faba* and *H. annus*	Suresh and Rai, 1987

C. equisetifolia	Decreased the seed germination, plumule and radicle growth of *O.sativa*	Jadhav and Gayner, 1995
Azadirachta indica	Aqueous leaf extract reduced germination of *P. typhoides, S. bicolor, C. cajan, C. tetragonoloba* and *V. radiata*	Bisla *et al.*, 1998
A. indica	Reduced growth of *V. faba, S. indicum, S. bicolor* and *M. uniflorum*	Palani and Dasthagir, 1998
Dalbergia sissoo	No effect on yield of understorey crops up to age of 11 year	Narwal,1996
D. sissoo	Reduced the yield of *S. bicolor* from third year.	Arya *et al.*,1998
Leucaena leucocephala		
L. leucocephala	Leaves, flowers, pods and seeds contain mimosine, which causes toxic effect on many plants.	Hegarthi *et al.*, 1976 ; Jones, 1981; Reis *et al.*, 1975
L. leucocephala	Mimosine inhibited germination and radicle growth of *L. sativa, O. sativa* and *L. perenne*	Wilson and Bell, 1979; Chou and Kuo, 1986

L. leucocephala	Second and third leaf extract boosted forage yield of *Z. mays, S. bicolor, P. trifolium* and *A. sativa.*	Gill and Patil,1981; Gill *et al.*, 1992; Parihar, 1990; 1994
L. leucocephala	Stimulated germination and seedling growth of *O.sativa*	Chou,1983
L. leucocephala	Inhibited radicle growth in *L. sativa* and *O.sativa*	Kuo *et al.*, 1983
L. leucocephala	Significant increase in productivity of *C. cajan, S. indicum, R. communis* and *S. bicolor*	Singh,1983
L. leucocephala	Suppressed growth and population density of *A. confusa, C. clauca* and *A. formosana*	Chou and Kuo, 1986
L. leucocephala	Radicle growth of *O. sativa, R. sativus, B. rapa, P.vulgaris, D. carota* and *B. pilosa* inhibited at 10 ppm concentration and promoted at 1ppm of mimosine	Tawata and Hongo, 1987
L. leucocephala	Yield of *Z. mays* improved under hedgerow and maximum when the hedgerow was cut to 10 cm.	Macklin *et al.*, 1988

L. leucocephala	Yield of *A. sativa* increased upto 40%	Pathak,1988
L. leucocephala	Inhibited seed germination in *O. sativa.*	Koul and Singh, 1989
L. leucocephala	Depressed the seed germination, root length and dry matter production in *S. bicolor, V.faba* and *H. annus.*	Swaminathan *et al.*, 1989
L. leucocephala	*Z. mays* yield decreased under unpruned conditions	Field and Matan, 1990
L. leucocephala	Reduced the seed germination of *O.sativa*	Koul *et al.*, 1991
L. leucocephala	Reduced the yield of *T. aestivum* and *V. radiata* from 3rd year onwards.	Deb Roy and Gill, 1991
L. leucocephala	Alley cropping decreased *S. bicolor* yields by 28 - 45 percent	Korwar and Radder, 1991
L. leucocephala	Reduced the seed germination of *L. sativa* and *L. perenne.*	Chou,1989
L. leucocephala	Had least allelopathic effect on grasses compared to other trees.	Chouhan *et al.*, 1992

L. leucocephala	The first extract showed inhibition, while third extract exhibited stimulatory effect on radicle growth of *O.sativa.*	Chaturvedi and Jha, 1992
L. leucocephala	Grain yield reduced up to 55 and 47 % in *Z. mays* and *T. aestivum,* respectively.	Chaturvedi and Jha, 1994
L. leucocephala	Inhibition of seed germination of *T. aestivum* and *O.sativa* which was directly proportional to the concentration of leaf extract.	Rao *et al.*, 1994
L. leucocephala	Reduced the growth of *S. bicolor, V.faba* and *C. tetragonoloba.*	Deshwal and Nandal,1996
L. leucocephala	*Leucaena* has a detoxification mechanism that degrades mimosine so that its own seedling growth is not inhibited by mimosine	Smith and Fowden, 1996
L. leucocephala	Decreased germination and seedling growth of *G.max, V. mungo* and *A. hypogaea.*	Velu *et al.*, 1996

L. leucocephala	Yield of *S. bicolor* increased upto 117% over control after complete decomposition of mulch	Wiegard and Jutzi, 1996
L. leucocephala	Yield of *T. aestivum* increased up to 25% over control by mulching at the rate of 2.25 t/ha.	Sharma *et al.*, 1997
L. leucocephala	The first extract inhibited, while third extract stimulated radicle growth of *G.max* and *V. mungo*.	Dharamraj,1998
L. leucocephala	Reduced yield of *V. radiata* and growth and yield of *E. officinalis*	Bisaria,*et al.*,1998
L. leucocephala	The yield of *G. max* decreased in 4 meter alley treatment over sole crop.	Solanki *et al.*,1999

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigations entitled **"STUDIES ON ALLELOPATHIC POTENTIAL OF SUBABUL *Leucaena leucocephala* (Lam.) de Vit"** were carried out in the laboratory, nursery and experimental farm of National Research Centre for Agroforestry, Jhansi located at an elevation of 300m above the mean sea level and situated between $24^0 11'$-$26^0 27'$N latitude and $78^0 17'$-$81^0 34'$E longitude during 1997-98 and 1998-99.

Climatic characteristics of the site

Meteorological data for the years 1998 and 1999 are tabulated in Annexure-I, II and III. During 1998, the maximum and minimum temperatures recorded were 47.4 ^{0}C on 28th May, 1998 and 1.0 ^{0}C on 20th January, 1998 respectively. However, the mean maximum and minimum temperature were 32.2 and 18.48 ^{0}C, respectively (Annexure-I). The highest amount of rainfall (102.7 mm) was recorded on 11thJuly,1998 . However, the average rainfall during the year was 905.60 mm. Five months viz. January, February, October, November and December remained dry during 1998 (Annexure-II). The maximum and minimum temperatures recorded during 1999 were 42.0^{0}c in April and 5.7^{0}c in January. However the mean maximum and minimum temperature were 32.54 and 17.56^{0}c, respectively (Annexure -I). The highest amount of rainfall 478.6 mm was recorded in the month of September and minimum 15.6mm during October 1999. However, the average rainfall during the year was 1118.2 mm. February, March, April, November and December were the dry months during this year(Annexure -III).

Edaphic characteristics of the site

The edaphic characteristics of the site revealed that the soil of the site was sandy clay loam consisting 45.2, 21.7 and 31.1 sand, silt and clay, respectively. The field capacity of the plot was 25.7% and permanent wilting point 8.3% with available moisture 215mm m^{-1}. The bulk density was determined as 1.48 g cm^{-3} at the time of initiation of the experiment. The pH of the soil was 7.4 with 0.19 dsm^{-1} electrical conductivity. Soil contained 0.46 % of organic carbon. The available nitrogen, phosphorus and potassium in soil were 214.8, 15.19 and 298.7 kg/ha, respectively.

Allelopathic factor

The allelopathic factor for these studies was *L. leucocephala* and the test companion crops on which the allelopathic influence was studied were *Glycine max* and *Triticum aestivum* . The description of the allelopathic factor and test plants are as under:

Leucaena leucocephala (Lam.) de Wit belonging to family Leguminosae and sub- family Mimosaceae is known as the `Miracle tree' due to its paramount economic importance. The common names of *L. Leucocephala* are *Ipil-Ipil* (Philippines), *Vaxim* (mexico), *Lamtora* (Indonesia), *Blackwood* (English), *Subabul* (Hindi). It is a fast growing, thornless, ever green leguminous woody perennial. As a tree it grows upto11m in height and 16 cm. in DBH in 7 years. It has feathery leaves, small white powder -puff flowers and with bunches of long brown pods.

Distribution

L. leucocephala a native of Southern Mexico (region of Chimpus and Yucatan) has been introduced in many countries of the

world namely Pacific Island, Philippines, Indonesia, Papua, New Guinea, Malaysia, Eastern and Western Africa and is now truly pantropical in humid region of average altitudes (up to 1300 m amsl) with hydrometric dry and wet reasons. It is a plant of tropic and subtropic regions growing up to an elevation of 500 m. It has colonised in the Pacific and South-East Asian region and has been favoured in the Philippines and Indonesia, Caribbean region and Mediter-ranean countries including Madagascar and Mauritius. It was introduced in India long ago and is now being extensively cultivated in Uttar Pradesh, Maharashtra, West Bengal, Andhra Pradesh, Orissa, Karnataka, Punjab and Himachal Pradesh. *L. leucocephala* was brought to India in the early 1950s for soil reclamation and as green manure. However, the Agricultural Development Bureau, Madras State failed by and large to cultivate interest among Indian farmers in intensive planting of *L. leucocephala*, therefore, it remains as hedge plant on boundaries and in backyards. Australian Scientists published series of research papers/articles during 1970-72 regarding the uses of *L. leucocephala* as a high protein, mixed rich fodder. The Indian Council of Agricultural Research (ICAR), was impressed by *L. leucocephala* as a promising source of fodder and fuel in India, notwithstanding Australian report of mimosine toxicity. After D.C. Brewbaker, University of Hawaii began providing seed of his Hawaiian Giant *L. leucocephala* (Salvadova type) in 1976, the popularity of *L. leucocephala* boosted to manifold.

Among legumes *L. leucocephala*, which was the most commonly talked MPTS in the country during the 1980s, provided a wide assortment of cultivars for multiple uses. Its rugged habit, deep root

system, abundant seed and quick growth enables it to establish even in unfavorable situations. *L. leucocephala* can grow on marginally productive soils and wastelands. It was promoted as being superior to traditional fodder crops such as *Sorghum bicolar* and *Zea mays*. The *L. leucocephala* produces seeds even in the first year.

At present, more than 100 varieties of this tree species are known, which can be broadly classified as the Hawaiian, Salvadora and Peruvian type (NAS,1977).

a) Hawaiian type is characterised as short bushy type up to 5m in height, flowering initiates at an early age (4-6 months old) and occurs almost the year round. Seeds are produced in abundance. Suitable for fuelwood and charcoal.

b) Salvadora type is tall, attaining 20 m in height, having large leaves, pods and with a branchless trunk. Some high yielding cultivars are called Hawaiian giant and are cultivated for timber and wood.

c) Peruvian type is also tall up to 15m but with short clean bole and extensively branching down the trunk. It is generally cultivated for forage production.

Environmental Requirements

It is a plant of the tropic and subtropic regions found throughout the plains up to 500 m elevation and fairly well up to 1300 m, though it can withstand large variation in rainfall, temperature, wind and drought (NAS,1977). It requires a warm climate, though the plant continues to grow at high elevations but without its lowland vigour. It stands high variation in rainfall, temperature, wind and drought. The plant is relatively temperature sensitive.

Rainfall : The best growth of *L. leucocephala* is obtained in areas with 600-1000 mm. annual rainfall, though it can grow in areas with 250 mm rainfall (NAS,1977). It can withstand drought. In Philippines, it is not considered as suitable for areas with very high rainfall such as with 1650 mm or more rainfall (Farinas,1952). Whereas, in dry locations with rainfall less than 500 mm, two irrigations per month from October-June in the first year are recommended to obtain optimum growth.

Temperature : Low temperature inhibits its growth, because it is very sensitive to low temperature. Light frost defoliates the plant and kills the growing tip; however, it sprouts again in spring.

Soil : The best growth performance were recorded on deep fertile soils which can supply adequate soil moisture, though it can grow on shallow soils as the root spread is mainly lateral. It is characterised by a well developed deep taproot system, capable of breaking an impervious soil layer (Gray,1968). Neutral to alkali soils are best suited for its growth; on acid soils plant growth is limited and soils below pH 5.0 and with a high alumina content limits its cultivation. Medium fertile soils with calcium are good for the establishment and growth of the species.

Silvicultural requirements

It can tolerate partial shade but grow best in full sun, as it is a light demanding tree. The seedlings cannot withstand thick shade of weeds or trees. It is fairly resistant to drought, though prolonged drought may kill seedlings on clay soils. Seedlings are frost tender and frost may cause defoliation and even results in dieback. The tree has a good coppicing power and allows repeated harvests and withstands browsing very well.

Phenology

It is an evergreen tree, frost or prolonged drought may, however, result in defoliation. The plant flowers and fruits at a very early age and vigorous plants produce seeds in the first or second year. It flowers during April to August but generally almost all the year round except during winters. Flowers are self pollinated. Fruit is dark brown, straight , flat, thin, 15-20 seeded pod, tapering at the base, appears during July to November but appears according to flowering. The pods develop quickly and mature in about 3-4 months. Pods split along the edges dehiscing seeds. Seed is dark brown in colour, small produced during February to May and July to November. There are about 23,600 seeds per kg. Seeds remain viable for 8-10 years if fumigated and stored in air-tight containers. Seeds require pretreatment with hot water for 5 minutes at 70 to 80^{0}C or conc. Hydrochloric acid or scarification for quick germination. Seeds germinates within 4 to 6 days of sowing.

Leaf fodder

Forage production from Cunningham variety planted in a single row at a spacing of 2 m in Jhansi was 0.75 and 1.94 kg/tree at 3 and 4 years of age, respectively, while Hawaiian Giant K-8 planted with a density of 5000 trees/ha yielded 7.5 tonnes of forage per hectare at 1.5 years of age (Pathak and Patil, 1980). A typical analysis of the leaf forage gave the following figures : dry matter, 89.4 per cent; crude protein, 24.2 per cent; ether extract, 4.4 per cent; crude fibre, 13.3 per cent; ash, 10.8 per cent; calcium, 1.98 per cent; phosphorus, 0.27 per cent; digestible protein, 19.7 per cent; total digestible nutrients, 57.3 per cent; gross energy (K cal/kg), 3,995 (International Consultation on Ipil-

Ipil Research). Mimosine comprises about 3 - 5 per cent (dry weight basis) of the protein of cultivated types.

Yield

Leucaena annual increments have been measured from 24 to more than 100 cu m/ha and average annual increments are expected to be between 30-40 cu m. The yield from different varieties at Jhansi over a period of 10 years were Salvador - 43.4; K 8 - 23.8 and K 28 - 26.4 tonnes/ha (Pathak and Patil, 1980).

Economic uses

The species is cultivated on community lands, farm bunds, pastures and wastelands for a variety of uses by the farmers and by the industries to meet their requirements for raw material. The figure represents the important uses of *L. leucocephala* to the farmers and beneficiaries. The most important economic uses of *L. leucocephala* are summarised below:

1. **Timber and Lumber Wood :** The wood of *L. leucocephala* is suitable for agriculture implement.
2. **Fuel Wood :** It makes excellent fuel wood and charcoal. The wood has a high density and calorific value 4200-4600 kcal kg^{-1} wood.
3. **Paper Pulp :** It has a potential as a major source for pulp and paper industry. Gum is a good additive (Plate -19) and useful in the paper industry (Hegde,1986).
4. **Reforestation :** Its ability to thrive on step slops on marginal

soils and in areas with an extended dry season make it a potential plant species for restoring forest cover to denuded wastelands, slops and grassland.

5. **Ornamental :** It is a suitable for planting in park, garden and avenues.

6. **Food :** In Central America and Indonesia young pods and seeds are edible. The seed contains 5% oil which is used for cooking or cosmetic preparation.

7. **Therapeutic :** Mimosine is considered therapeutic as a contraceptive. The flower, leaves and root, bark are also used.

8. **Grazing :** More than half the live stock i.e. sheep and goats, depend on free grazing. Due to high cost of fencing there is often little incentive for farmers to plant *Leucaena* to feed their own live stocks (Hegde,1991).

9. **Green Manure :** It can be used as green manure. Mineral content in dried leaves nitrogen 22-43% by weight ,phosphorus 0.2-0.4%, potassium 1.3-4.0%, Calcium 0.8-2.0% and Magnesium 0.4-1%.

10. **Soil Improvement :** It is nitrogen fixing tree which help to enrich soil through atmospheric nitrogen fixation. The leaf fall enriches the soil through decomposing leaf litter. The aggressive root system break-up impervious sub soil layer improving moisture penetration and decreasing surface run off.

Limitations

Although, *L. leucocephala* is very useful, it also have some demerits that the *L. leucocephala* is heavily branched, so need expensive fencing to protect it from animal, even in forest. Another,

problem is that as *L. leucocephala* bend towards sunlight or open space it is produces crooked poles, and the wood is also not durable, because it is prone to insect and fungal attack. Heavy seedling is a draw back when It is grown as a wind break. The mimosine contents with excessive intake poses problem with hair of sheep.

Companion crops

I) Soybean *(Glycine max* L) : It belongs to family Leguminosae subfamily Paplionaceae which is an important pulse as well as oil yielding plant with other industrial significance. It is a native of southeastern Asia and enjoys the cultivation of over a thousand varieties.

Botany : It is a small, bushy, erect or prostrate annual resembling the cowpea. The height of plant varies from 1 to 6 feet. The leaves are trifoliate. Flowers are born in short axillary racemes. The pods are hairy and dark brown in colour. It contains 3-4 seeds.

Cultivation : *G.max* is grown alone or mixed with *Z. mays* or *S. bicolor*. The seeds are sown in June or July in a well prepared soil. The best growth is obtained on fertile loam or sandy loam soils.

G.max has 32-42% protein content which is higher than many vegetable sources of protein. As it has the highest lysine content (6.8%) it can combine very well with cereals poor in lysine but rich in sulphur containing amino acids. It constitutes a very nutritious food being very rich in protein content. The various amino acid contents in *G.max* are Lysine - 6.8; Tryptophan - 1.4; Phenalalanine - 5.3; Methionine - 1.7; Threionine - 3.9; Leucine - 8.0; Isoleucine - 6.0; Valine - 5.3; Arginine - 7.2; Cystine - 3.1 and Histidine - 2.4 per cent.

It is eaten green, roasted as an appetizer or made into flour that is used with other flours to make breakfast food, bread etc.. Besides these, It has manifold uses. Today, *G.max* oil is amongst the most important of all the articles derived from it. It is also an excellent food for diabetics. Milk extracted from seeds is used for cooking and is also prescribed for infants and invalids.

In India, *G.max* is grown as kharif crop. The yield of *G.max* of last few years in India are as follows: 33.9; 47.5; 39.3; 50.9; 52.0; and 65.2 lakh tonnes during 1992-93; 1993-94; 1994-95; 1995-96; 1996-97 and 1997-98, respectively. The above data indicate gradual increment in yield of *G.max* from 1992-93 which was maximum during 1997-98 (Hegde and kiresur, 1999).

ii) Wheat (*Triticum aestivum* L.) : It belongs to the family Graminae, and is an important cereal crop with an export potential. It is a principal cereal of the world especially in the temperate region.. It is estimated that cultivation of *T. aestivum* is about 6000 years old and its origin is in Iraq. Others believe Syria and Palestine to be its centres of origin. Half of the world's population is dependent on *T. aestivum* as a major staple food.

Botany : It is an annual grass belonging to genus *Triticum*. The plants generally attain a height between 2 to 5 feet. Like most other cereals it produces branches known as tillers. The roots are fibrous. At the end of the vegetative season `shooting' of the ear or booting occurs, where inflorescence are produced. Inflorescence is a spike, consisting of 15-20 spikelets borne alternately on the rachis thus giving a zigzag appearance. A spikelet consists of 1-5 flowers enclosed by a pair of

glumes. The mature edible grain is a one seeded dry fruit - caryopsis where seed coat remains fused with the pericarp. A mature grain has an embryo, a starchy endosperm, nitrogenous aleurone layer and the husk.

Climate and soil : *T. aestivum* requires temperate climate. It requires 10^0C temperature at the time of sowing, 10 to 16 ^{0}C at sprouting time and about 20 ^{0}C at the maturation of grains. It also needs clear skies and minimum of 90 days of sunshine besides 100 days of frost free period. About 35 to 60 cm rainfall per year is almost suitable for *T. aestivum.* It can not be successfully grown where annual rainfall exceeds 80cm. However, in regions with annual rainfall less than 25 cm, it grows with the help of irrigation.

T. aestivum is known to grow over a wide range of soil type, highest yields being obtained in heavy loams e.g. silt and sandy loams. It can be made to grow in a less fertile soil by addition of fertilizers like nitrogen, ammonium sulphate etc. Also rotation of crops in these areas has been found rewarding.

Cultivation : The land is cleared thoroughly before cultivation for *T. aestivum* is easily choked by weeds. The fields are ploughed 4-5 times before sowing. Heavy, well developed and ripe seeds give a good crop. Moisture is essential for uniform germination. The seeds are sown deep in rough, dry and light soils and shallower in moist and heavy soils. The sowing begins in early October upto middle of November, varying with the climatic conditions by different varieties. The late sowing is avoided for the fear of infection of rust.

In India *T. aestivum* is grown as rabi crop. The yield of *T. aestivum* (in million tonnes) of last few years in India are as follows: 57.2; 59.8; 65.8; 62.1; 69.3; and 66.0 during 1992-93; 1993-94; 1994-

95; 1995-96; 1996-97 and 1997-98 (Nagarajan,1999). This indicates gradual increase in yield of *T. aestivum* from 1992-93 which was maximum in 1996-97. Per hundred gram of *T. aestivum* seed have 11.8g protein, 71.2 g carbohydrate, 1.5g fat, 1.2g crude fibre, 1.5 mineral matter, 41.0 mg calcium, 306 mg phosphorus.

The entire programme of the study was classified into the following three sections:

1. Allelopathic studies under laboratory conditions
2. Allelopathic studies under nursery conditions and
3. Allelopathic studies under field conditions

Allelopathic studies under laboratory conditions

Aqueous extract of fresh leaves, flowers and pods :

The studies on allelopathic influence of aqueous extract of leaves, flower and pods were conducted in the laboratory of NRCAF, Jhansi. during 1997-99. Fresh leaves of *L. leucocephala* were collected at 7 a.m. in the morning from ten year old trees growing in the experimental farm during first week of August, 1997. The ambient temperature and relative humidity were $34^{o} \pm 2^{o}$c, 70-72 %, respectively. Five hundred gram fresh leaves were kept in 500 ml distilled water for 24 hours. Such soaked leaves were blended for two minutes in a blender and a paste was obtained. The paste was further diluted with an equal amount of glass distilled water and filtered through Whatman No. 1 filter paper. The filtrate was centrifuged at 10,000 rpm for 5 minutes using ultra centrifuge. The supernatant liquid obtained through centrifugation was filtered through Whatman No. 1 filter paper. This aqueous fresh leaf extract was further diluted with glass double distilled water to obtain

20, 40, 60, 80 and 100 % concentration. The flowers and pods were collected during April,1998. One hundred gram flowers and pods were grinded in a grinder for two minutes and diluted with 100 ml glass distilled water. The filtrate so obtained was filtered through Whatman No. 1 filter paper and centrifuged at 10,000 rpm for 5 minutes. The aqueous extract obtained was further diluted to obtain 20, 40, 60, 80 and 100% concentrations. The seeds treated with distilled water were considered as control treatment. One hundred seeds of *T. aestivum* and *G. max* were soaked in each concentration for twenty four hours. Twenty seeds of *T. aestivum* and *G. max* were placed in each petriplate (15 cm diameter) lined with two layers of filter paper moistened with glass distilled water. Three petriplates of twenty seeds for each treatment were taken into account. The experiment was repeated thrice. The same experiment was conducted next year for fresh leaves in August, 1998 and flowers & pods in April, 1999.

Aqueous extract of decomposed leaves :

Decomposed leaves were collected beneath the ten year old plantation of *L. leucocephala* and sample of 500g was taken during May, 1998 and repeated in May, 1999. The sample was soaked in 500 ml distilled water for 24 hours, filtered through Whatman No. 1 filter paper and centrifuged at 10,000 rpm for 10 minutes. The supernatant liquid was filtered through Whatman No. 1 filter paper. Extract of decomposed soil was further diluted with glass double distilled water obtained 20, 40, 60, 80 and 100 % concentration. Distilled water was considered as control. One hundred seed of *T. aestivum* and *G. max* were soaked in each concentration for twenty four hours. The

procedure was same as used for aqueous extract of leaf, flower and pod. The experiment was repeated thrice.

Observations

Regular observations on seed germination, shoot, root and seedling length, shoot-root ratio, fresh and dry weight of shoot, root and seedling and moisture content were taken in the following manner :

Seed germination (%) : Daily germination was recorded for a period of seven days from third day onwards. It was the per cent of seeds germinated at the completion of germination in petriplates.

Shoot length (cm) : The shoot length was measured with a scale from collar region to the shoot tip of the seedling after completion of germination. For taking shoot length ten seedlings were taken for each treatment and average shoot length was calculated.

Root length (cm) : The root length was measured with the help of scale from collar region to the tip of the longest root, after removing the seedling from the petriplate and utmost care was taken that roots were not damaged. It was the average length of five roots recorded per seedling.

Seedling elongation (cm) : The seedling elongation was taken by adding shoot and root length of the same seeding.

Shoot -root ratio : It was calculated by dividing shoot length by root length of the seedling.

Fresh shoot weight (g) : The seedlings were removed from the petriplate, the excess of water was removed with the help of filter paper. The shoot portion was separated from the seedling and fresh shoot weight was taken using electronic top pan balance.

Fresh root weight (g) : The root portion separated from the seedling was placed on the electronic top pan balance and fresh root weight was observed.

Fresh seedling weight (g) : The seedling weight was recorded by summing up the fresh shoot and root weight of the same seedling.

Dry shoot weight (g) : The shoot portion was kept in hot air oven at 80^0C for 48 hours for drying and dry weight was determined using top pan balance.

Dry root weight (g) : The root portion was kept in hot air oven at 80^0 C for 48 hours for drying and dry weight was determined using top pan balance.

Dry seedling weight (g) : The seedling weight was recorded by summing up the dry shoot and root weight of the same seedling.

Moisture content (g) : The moisture content for shoot, root and seedling was calculated by subtracting dry weight from the fresh weight of shoot, root and seedling, respectively.

Moisture content (%) : The dry weight of the shoot, root and seedling was subtracted from the fresh weight of the same, respectively and divided by the fresh weight and multiplied with hundred to determine moisture content percentage as presented in the following formula, where FW is fresh and DW is dry weight of the seedling.

$$\textbf{Moisture percentage} = \frac{FW - DW}{FW} x100$$

Statistical analysis

The observations recorded for both the years were pooled for each parameter. The data was analysed statistically as per the design, Completely Randomised Design (CRD) and analysis of variance

(Anova) was worked out using SPSS (Statistical Package for Social Science) and tables were compiled and prepared accordingly. The graphic presentation was computed from the data by using Harward Graphics (4.0) software package.

Allelopathic studies under nursery conditions

Studies were carried out in the nursery of NRCAF Jhansi to elucidate the influence of soil of *L. leucocephala* plantation on the germination and seedling growth of *G. max* and *T. aestivum.* Soil was collected from 1.0 cm deep of top soil beneath the ten year old plantation of *L. leucocephala.* Four grades of soil mixture were prepared, which are as under:

1. Soil of *L. leucocephala* plantation alone (1:0)
1. 25% soil of *L. leucocephala* plantation +75 % field soil (1:3)
2. 50% soil of *L. leucocephala* plantation + 50% field soil (1:1)
4. Field soil alone (0:1)

The above mention soil mixtures were filled in polythene bags (11 x 25cm) and left as such for two days. Ten seeds of *G. max* were sown in each polythene bags during July, 1997 and repeated in 1998. Three replication of ten polythene bags each were considered for each treatment. The poly bags were mulched with dry grass and irrigation was applied daily until the completion of germination and thereafter weekly. Weeding was done manually. BHC @ 1.0 per cent was applied after the completion of germination as a protection against the termites. Studies on germination of *T. aestivum* were carried out in the month of November 1997 and repeated in 1998 adapting the same procedure.

Observations

The observations were recorded for seeding germination, shoot length, root length, shoot-root ratio, fresh and dry weight of seedling and moisture content for all the treatments in nursery by adopting the the same procedure as for observations for laboratory studies.

Statistical analysis

The data recorded for both the years were pooled for each parameter and was analysed statistically as per the design, Randomised Block Design (RBD) and analysis of variance (ANOVA) was worked out using SPSS (Statistical Package for Social Science) and tables were compiled and prepared accordingly. The graphic presentation was computed from the data by using Harward Graphics (4.0) software package.

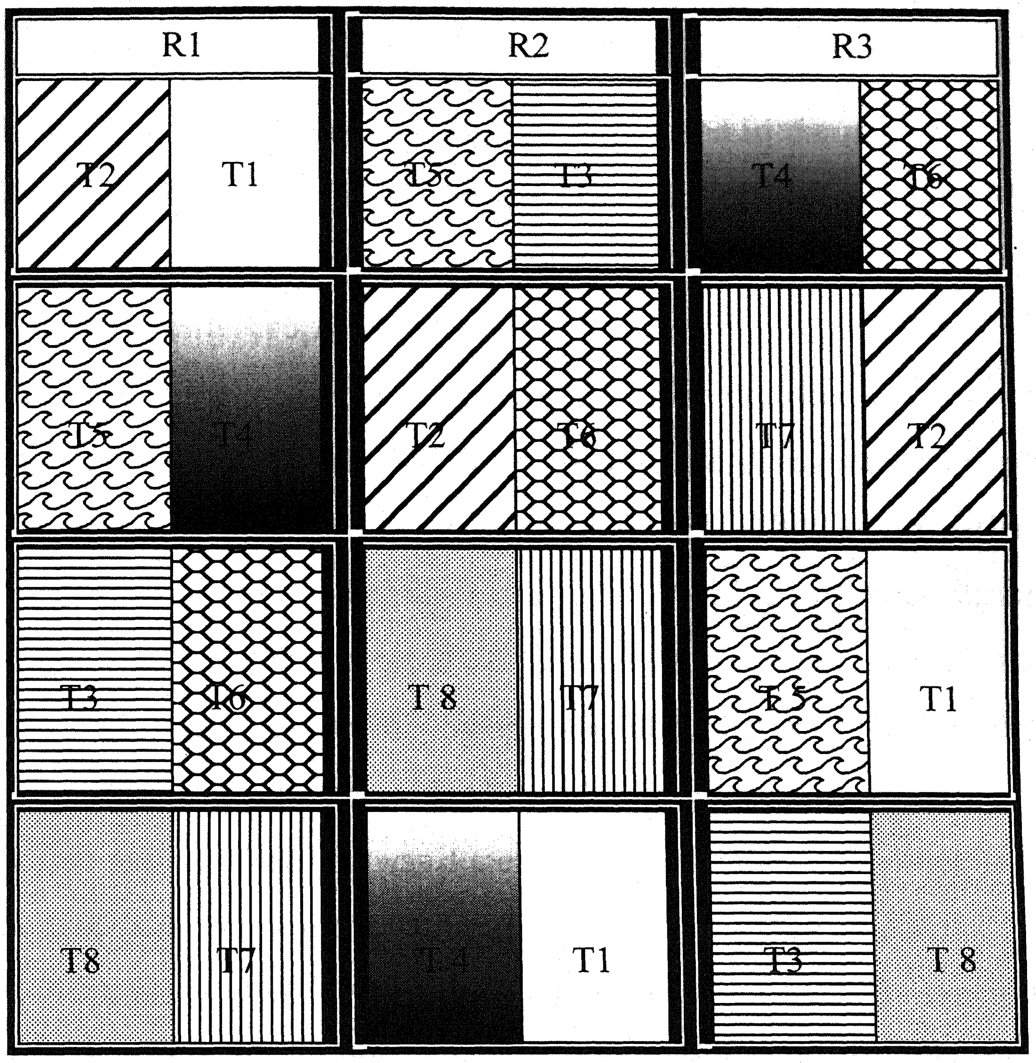
Allelopathic studies under field conditions

The field studies were conducted in the Central Farm of NRCAF, Jhansi. The experiment was laid out in Randomised Block Design with eight treatments and three replications. There were 16 trees per treatment at a spacing of 2.5 x 2.5 m. Thus the plot size for each treatment was 10 x 10 m. The total experimental area was 0.24 hectare. The different treatments were :

T1 = Sole Tree;	T5 = Tree + Crop;
T2 = Sole Crop;	T6 = Tree pruned + Crop;
T3 = Tree pruned;	T7 = Tree pruned + mulch + Crop;
T4 = Tree pruned + mulch;	T8 = Crop + mulch

G. max and *T. aestivum* were taken as intercrops during kharif and rabi seasons, respectively, in between the *L. leucocephala* rows. The field lay out of the experiment is as under :

Layout of The Field Experiment



T1 = Sole Tree;	T5 = Tree + Crop;
T2 = Sole Crop;	T6 = Tree pruned + Crop;
T3 = Tree pruned;	T7 = Tree pruned + mulch + Crop;
T4 = Tree pruned + mulch;	T8 = Crop + mulch

Planting of *L. leucocephala* : The pit positions were marked in the field, with help of crow bar during layout preparation. The pits of the 45 x 45 x 45 cm were dug after the layout. The pits were field with the normal field soil and FYM. The *L. leucocephala* seedlings of uniform height and collar diameter (one year old) raised in the nursery were planted in the field during February, 1997. In total there were 384 seedlings of *L. Leucocephala* were planted.

Sowing of Intercrops

***G. max* :** Prior to sowing of the crop field was prepared and leveled with the help of tractor mounted cultivator and disk plough. Proper layout was prepared according to the treatments. The *G. max* variety PK- 472 was sown in the interspaces of *L. leucocephala* trees during kharif season following standard package of practices. In 1997, the sowing was done on 5th July by applying 80 kg/ha seed. The fertilizer dose of 160 and 64 kg/ha of DAP and MOP, respectively was applied before sowing. Weeding was done manually to reduce the competition between the crop and the weeds. The harvesting of the crop was done on 10th November, 1997. During 1998, *G. max* was again taken as intercrop during kharif season and same procedure was followed.

***T. aestivum* :** As in the casc of kharif season crop, the field was prepared with the help of tractor mounted cultivator and disk plough and leveling was done for rabi season crop. The layout was prepared according to the treatments. Pre sowing irrigation was given in the second week of November. *T. aestivum* variety WH-147 was taken as intercrop during rabi season. The crop was cultivated following the standard package of practices for the region. The sowing of the crop was done on 20th November, 1997 by applying 120 kg/ha seed. The

fertilizer dose of 140,120 and 80 kg/ha of DAP, Urea and MOP, respectively was applied before sowing. One hundred twenty kg/ha Urea was applied for top dressing after first irrigation. Weeding was done manually to reduce the competition between the crop and the weeds. Three irrigations were applied on 10th & 30th December, 1997 and 20th January, 1998. The harvesting of the crop was done on 22nd April, 1998. In 1999 rabi season, *T. aestivum* was taken again as intercrop during and same procedure was followed.

Observations

Tree component : The observations recorded for tree component were divided into two groups i.e. growth and physiological parameters. The observations were recorded for four central trees for each treatment, to remove the effect of adjacent treatments on the performance of treatment under consideration. Then average value for each parameters was calculated by dividing it with four to obtain the values used for results.

Growth parameters

The data for plant height and collar diameter were taken four times in year i.e. once in all the seasons for all the treatments in the following manner :

Tree height : The tree height was measured by using measuring tape. The height was taken from tree base to the tip of the longest shoot. The height was measured in meters and up to the two decimals of centimeters and denoted as m in the text.

Collar diameter : The collar diameter was measured at the collar region of the trees. It was measured with the help of Vernier callipers. The collar diameter was measured at two angels for each tree and

average value was taken into consideration. It was measured in centimeters and referred as cm in the text.

Physiological parameters : The data for Relative Humidity (RH), Photosynthetically Active Radiation (PAR), Rate of Transpiration (RT) and Diffused Resistance (DR) were recorded for each treatment on four centrally located trees with the help of Steady State Porometer (LI-1600). These observations were taken at the leaf surface of the trees. For each parameter observations were taken on 5 leaves of each tree and then average value was obtained. The data was recorded in each season to study the effect of season on these parameters and following units were used .

Relative Humidity : The value of relative humidity was expressed in percentage.

Rate of Transpiration: It was measured as g $cm^{-2}s^{-1}$

Leaf Temperature : It was measured in degree centigrade and denoted as ^0C in the text.

Diffusive Resistance : The diffusive resistance was expressed as scm^{-1} in the text.

Crop component : Regular observations were recorded for various growth and physiological parameters for both the crops.

Growth parameters : In case of *G. max,* the data were recorded for plant population, plant height, number of branches, number of pods, seed weight, and yield. For, *T. aestivum* data were recorded for plant population, plant height, number of tillers, number of effective tillers, seed weight and grain yield. The data for growth parameters were recorded by taking the tree in the centre so that the influence of tree on the parameters is clearly reflected.

Plant Population : The plant population was recorded by counting the number of plants surviving in one meter row of the crop.

Plant height : It was measured similarly as in the case of tree component and expressed in centimetres.

Number of branches : It is the average number of branches per plant calculated by dividing the number of branches with number of plants taken into account.

Number of pods : It the average number of pods per plant calculated for each treatment.

Number of total and effective tillers : These are average number of tillers per plant and effective tillers were calculated as those which produced seed.

Seed yield : Seed yield was calculated for each plot by taking tree in the centre of the plot and expressed as quintal per hectare.

Physiological parameters : These were recorded similarly as in the case of tree component.

Determination of Mimosine content : The amino acid mimosine (β-N- (3-hydroxy-4-pyridone)-α-amino propionic acid) was first reported from *Mimosa pudica* L. as mimosine and later from *L. leucocephala* . Early studies revealed that it occurred at high concentrations (3-5% dry weight) in many tissues of Leucaena.

Methodology : The mimosine content in leaves, flowers and pods was estimated according to Brewbaker and Steve (1984). For the estimation of mimosine following reagents were prepared :

Reagent A : 0.1 N HCl

Reagent B: 0.1 N HCl with 1.5 g activated charcoal (kept in suspension during use with the help of a magnetic stirrer).

Reagent C : 1 g $Na_2EDTA.2H_2O$ in 500 ml of 0.1 N HCl.

Reagent D : 60% $FeCl_3$ solution, obtained by dissolving 4 g of $FeCl_3.6H_2O$.

Collection and assay of samples : About 10 g of fully open leaves on healthy branches were collected and dried at or below 40^0C until no further weight loss occurred. Weighed about 1.0 g of the dried sample and placed in a volumetric flask with 100 ml of reagent A (0.1N HCl) and macerated with the help of a blender. It can be stored at this stage at room temperature. Then about 10 ml of aliquot of the macerate was placed in a boiling bath tube (care was taken to insure that suspension was uniform by shaking before pouring). Then 15 ml of Reagent B (0.1 N HCl with charcoal) was added and boiled for 15 minutes. The tubes were placed in a beaker above Bunsen burner covered with aluminium foil. This resulted in 250 times dilution of the dry matter sample. Then it was filtered through Whatman filter No. 2.

Estimation : To estimate mimosine content 2 ml of aliquot of the filtrate was taken and added 5 ml of Reagent C plus 1 ml of Reagent D and kept the sample for 15 minutes in dark for full colour development. Then read the optical density at 535 nm using Spectrophotometer Spectronic-20. The reading was corrected against a blank achieved by diluting 2 ml sample of filtrate with 5 ml Reagent C plus 1 ml water (in lieu of Reagent D). A standard curve using solutions containing mimosine between 0.0025 and 0.025% (in 0.1 N HCl), treating 2 ml aliquots was prepared. The optical density of sample was determined by appling it to the standard curve and estimated the mimosine percentage as

Mimosine % = O.D. x 250.

The same procedure was adopted for determining the mimosine content in flowers and pods.

Estimation of metabolites :

(i) Nitrogen

Micro Kjeldahl's method (A.O.A.C., 1975) was adopted for determining the total nitrogen including organic nitrogen and nitrate nitrogen in the samples. One hundred mg oven dried leaves were taken in a clean, dried Kjeldahl flask containing 5 ml conc. H_2SO_4 (nitrogen free) along with catalytic mixture (catalytic mixture = K_2SO_4 + $CuSO_4.5H_2O$ in 5 : 1 ratio) and kept for digestion. The digested material was transferred into a volumetric flask and final volume was made upto 50 ml with the help of distilled water. One ml aliquot was taken into distillation apparatus along with 10 ml of 40% NaOH. Later on ammonia was distilled in 4% boric acid containing 2-3 drops of mixed indicator. Then distilled the sample for 7-10 minutes and titrated the distilled off ammonia with the standard H_2SO_4. The per cent nitrogen was calculated by the following formula :

$$\text{Per cent Nitrogen} = \text{Sample - blank x} \frac{\text{normalityof } H_2SO_4 \text{ x } 14 \text{ x } 100}{\text{sample weight x } 1000}$$

(ii) Phosphorus : Total phosphorus content was estimated in dried samples as per the method described by Olsen et al.,(1954). One g of leaves digested in Tri acid mixture ($H_2SO_4 + HNO_3 + HClO_4$ in 9 : 3 : 1 ratio) were taken in a volumetric flask along with 5 ml Metavandate reagent and diluted to 25 ml with distilled water. After colour development reading was taken with the help of Spectrophotometer using blue filter (480 nm) and phosphorus content was calculated using standard curve of phosphorus.

Metavandate reagent : A - 1.25 g metavandate in 300 ml boiling distilled water; B - 2.5 g ammonium molybdate in 400 ml of hot distilled water. Then mixed A and B solutions in 250 ml HNO_3 and diluted to 1000 ml with distilled water.

(iii)Potassium, Calcium and Sodium : These were estimated in according to Johnson and Ray method using flame photometer. Five hundred g fresh leaves were dried. The one g of these dried sample was digested in 10 ml Tri acid mixture ($H_2SO_4 + HNO_3 + HClO_4$ in 9 : 3 : 1 ratio). The digested material was filtered through Whatman filter paper No. 12 in a volumetric flask and final volume was made upto 100 ml. Then 1 ml of the sample solution and 1 ml of Metavandate reagent was added and diluted to 25 ml with distilled water. After colour development reading was taken with the help of Spectronic - 20 and phosphorus calcium and sodium content were calculated using standard curves.

Estimation of Total Phenols : Total phenols were estimated according to method proposed by Bray and Thorpe, (1954). Principle of estimation of phenols was done with Folin -Ciocalteu reagent based on the reaction between phenols and an oxidizing agent phosphomolybdate which results in the formation of a blue complex. The intensity of the colour was measured in a spectrophotometer.

Folin - ciocalteu reagent : 100g Sodium tungstate ($Na_2MO_4.H_2O$) and 25 g Sodium molybdate ($Na MoO_4.2H_2O$)in 700 ml water was dissolved 1000 ml flask. Further 50 ml of 85% Orthophosphoric acid $(H_3PO)_4$ and 100 ml concentrated HCl was added and boiled under reflux gently for 10 hr, cooled and 150g Lithium sulphate (Li_2SO_4) was dissolved in 50 ml water and 4-5 drops of liquid bromine were added . The mixture was

boiled without condenser for 15 minutes to remove the excess of bromine, it was diluted to the final volume with water and filtered. The reagent was of golden yellow in colour and was stored in amber coloured bottles. Just before use, one volume of this stock solution was diluted with two volumes of water.

Methodology : One ml of the extract was taken in a graduated test tube and added 1 ml of Folin-ciocalteu reagent followed by 2 ml of $Na_2 CO_3$ solution. The test tube was heated in boiling water bath for 1 minute and cooled under running tap. Diluted the blue solution to 25 ml with water and measured its absorbance at 650 nm in a Spectrophotometer (Model Milton &Roy USA). A blank containing all the reagents minus plant extract was used to adjust the absorbance to zero. The estimation of phenols was done with the help of standard curve made from the different concentrations of catechol.

Crude Protein : The estimation of crude protein was done by Kjeldahl`s apparatus using dries leaf samples as per A.O.A.C.(1994) methods. The crude protein estimated for different treatments is given in percentage of g/kg of dry matter.

Statistical analysis

The observations recorded for both the years were pooled for each parameter. The data was analysed statistically as per the design, Randomised Block Design (RBD) and analysis of variance (ANOVA) was worked out using SPSS (Statistical Package for Social Science) and tables were compiled and prepared accordingly. The graphic presentation was computed from the data by using Harward Graphics (4.0) software package.

Physico - chemical characteristics of the soil of the experimental field are tabulated below :

S.N.	Soil Characteristic	Value	Method	Reference
1	Mechanical Composition			
a) b) c)	Sand (%) Silt (%) Clay (%)	45.2 21.7 33.1	Bouyoucos hydrometer method	Bouyoucos, 1962
	Textural class	Sandy clay loam		
2	Soil moisture characteristics			
a)	Field capacity(%)	25.7	Pressure Plate apparatus	Richards, 1947
b)	Permanent wilting point (%)	8.3	Pressure membrane apparatus	
c)	Available soil moisture (mm m^{-1})	215	Pressure Plate apparatus	Richards, 1947
d)	Bulk density (g cm^{-3})	1.48	Core sampler	Piper, 1950
3	Physico- chemical properties			
	Soil pH (1:2.5: : Soil : Water)	7.4	Combined glass electrode pH meter	Jackson, 1958
	Electrical conductivity (d Sm^{-1} at 25x C)	0.19	Solubridge method	Richards, 1954
	Organic carbon (%)	0.46	Walkley and Black`s rapid titration method	Jackson, 1958
	Available N (kg/ha)	214.85	Alkaline $KMnO_4$ method	Subbiah and Asija, 1956
	Available P (kg/ha)	15.19	Olsen`s Method	Olsen et al., 1954.
	Available K (kg/ha)	298.7	Flame photometer method	Toth and Prince, 1949

Summary of Multiple Uses of `Subabul'
(*Leucaena leucocephala*)

Leucaena leucocephala

- ⇨ Increases fodder availability
- ⇨ Suitable for forestation, reforestation and agroforestry programmes
- ⇨ Most suitable tree species for arid, semiarid and tropical regions
- ⇨ Suitable for rehabilitation of degraded lands
- ⇨ Improvement in soil conservation
- ⇨ Provide shelter for animals
- ⇨ Improves soil fertility status
- ⇨ Facilitate agrobased paper industry
- ⇨ Provide therapeutic treatments
- ⇨ Pods are the source of human food
- ⇨ Source of fuel wood, timber and lumber wood for fencing, furniture, doors, windows
- ⇨ Source of employment generation
- ⇨ Improves socio- economic status of farmers.

RESULTS

RESULTS

The studies on allelopathic potential of subabul on wheat and soybean were carried out at the experimental farm of National Research Centre for Agroforestry, Jhansi during 1997-1999. The results obtained on the basis of three related experiments have been described in this chapter under the following sub heads :

1. Allelopathic influence under laboratory conditions
2. Allelopathic influence under nursery conditions and
3. Allelopathic influence under field conditions

Allelopathic influence under laboratory conditions

The influence of aqueous extract of leaves, flowers and pods of *L. leucocephala* was determined on the seed germination and seedling growth of wheat (*T.aestivum*) and soybean (*G. max*) under laboratory conditions and the result of which are presented in figures 1-2 and tables 1-16.

The germination initiated on 3rd day and its speed accelerated thereafter. However, pronounced speed of germination was observed on 7th days (Fig-1). The process of germination ceased on 10th day. The pretreatment of aqueous extract of leaves stimulated seed germination up to a concentration of 60% and reduced drastically at 80 and 100% (Fig -1).

The root, shoot and seedling elongation were measured on 10th day. It is evident from the data presented in table -1 that the pre application of aqueous extract of leaves significantly promoted the shoot and root length at 40% concentration, reduced at 60 and 80% and

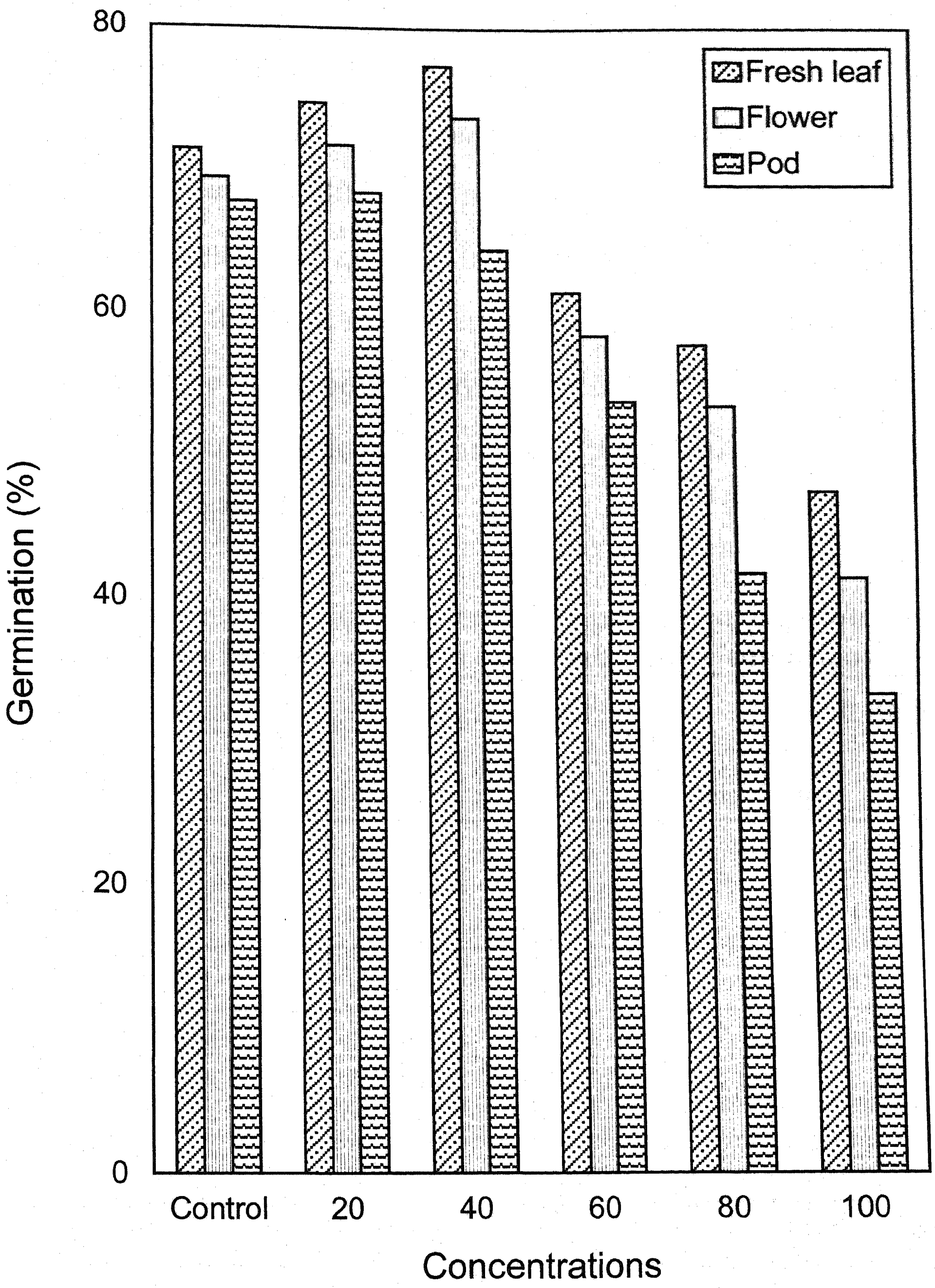


Fig. -1: Effect of extract of *L. leucocephala* fresh leaf, flower and pod on the seed germination in *G. max.*

drastically inhibited at 100% concentration (Table-1), as compared to control. The reduction at 100% was approximately 50% over control. The effect on seedling elongation exhibited the similar trend, the maximum (28.4 cm.) at 40 % and minimum at 100%(12.8cm.) which differs significantly from all other treatments .

The trend for shoot -root ratio showed that treatment of 20 and 40% increased the shoot root ratio over other treatments, insignificantly affected at 60% and drastically reduced at 80 and 100% concentration in *T.aestivum* (Table-1).

Table 1 : Effect of fresh leaf extract of *Leucaena leucocephala* on the shoot and root in *Triticum aestivum* under laboratory conditions

Treatment	Shoot length(cm)	Root length (cm)	Seedling elongation(cm)	Shoot Root ratio
Control	13.5	9.4	22.9	1.43:1
20	14.4	10.1	24.5	1.42:1
40	17.1	11.3	28.4	1.51:1
60	11.8	9	20.8	1.31:1
80	8.7	6.9	15.6	1.26:1
100	7	5.8	12.8	1.20:1
C.D. (.05)	1.8	0.8	3.6	N. S.

The pretreatment of leaf extract significantly enhanced the fresh weight of shoot, root and seedling 1.332,0.980 and 2.31g, respectively, at 40% which differs significantly from all other treatments and the minimum values were observed at 100% concentration (0.415, 0.297, 0.712g) in *T. aestivum* (Table - 2). The dry matter production exhibited almost similar trend in respect of effect of treatment, (Table-2).

Table - 2: Effect of fresh leaf extract of *Leucaena leucocephala* on *Triticum aestivum* under laboratory conditions

Treatments	Control	20	40	60	80	100	CD (.05)
Fresh weight (g)							
Shoot	0.902	1.005	1.332	0.898	0.55	0.415	0.281
Root	0.81	0.96	0.98	0.633	0.411	0.297	0.187
Seedling	1.712	1.965	2.312	1.531	0.961	0.712	0.541
Dry weight(g)							
Shoot	0.250 (27.72)	0.290 (28.86)	0.381 (28.61)	0.240 (26.73)	0.151 (27.46)	0.094 (22.66)	0.1
Root	0.211 (26.05)	0.218 (22.71)	0.235 (23.98)	0.164 (25.91)	0.098 (23.85)	0.076 (25.59)	0.105
Seed ling	0.461 (26.92)	0.508 (25.85)	0.616 (27.00)	0.404 (26.38)	0.249 (25.91)	0.170 (23.87)	0.103
Moisture Content (g)							
Shoot	0.652 (72.28)	0.715 (71.14)	0.951 (71.39)	0.658 (73.27)	0.399 (72.54)	0.321 (77.34)	0.139
Root	0.599 (73.95)	0.742 (77.29)	0.745 (76.02)	0.469 (74.09)	0.313 (76.15)	0.221 (74.41)	N.S.
Seedling	1.251 (73.08)	1.457 (74.15)	1.696 (73.00)	1.127 (73.62)	0.712 (74.09)	0.542 (76.13)	N.S

Value in parenthesis indicates percentage

Moisture contents were not affected significantly due to treatment in root. However, this attribute was significantly promoted in shoot at 40% concentration (0.951g)and thereafter reduced with increasing concentrations (Table-2).The moisture content in seedling of *T.aestivum* was not affected significantly due to pretreatment of aqueous leaf extract of *L. leucocephala* (Table-2).

The exogenous pretreatment of seeds with aqueous extracts of *L. leucocephala* flowers promoted seed germination at 40%, had no significant effect at 20-60% and reduced at 80 and 100% concentrations (Fig-2) in *T.aestivum*. The length of shoot increased up to 40% concentration and decreased at 60-100% concentrations in a same manner. More than 50% reduction in shoot length was observed at 100% concentration. Similarly the length of root was stimulated at 20 and 40% and inhibited at 60-100% concentrations over the control and exhibiting similar trend for seedling elongation in *T.aestivum*(Table-3).

Table 3: Effect of flower extract of *Leucaena leucocephala* on the shoot and root in *Triticum aestivum* under laboratory conditions

Treatment	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot root ratio
Control	9.8	7.1	16.9	1.38:1
20	11.6	8.9	20.5	1.30:1
40	14.3	11.3	25.6	1.26:1
60	7.8	6.1	13.9	1.27:1
80	4.9	3.9	8.8	1.25:1
100	4.1	3.5	7.6	1.17:1
C.D. (.05)	1.7	1.4	2.9	N.S.

The fresh weight of shoot, root and seedling was found significantly higher (Table-4) at 40% concentration (1.332,0.980,

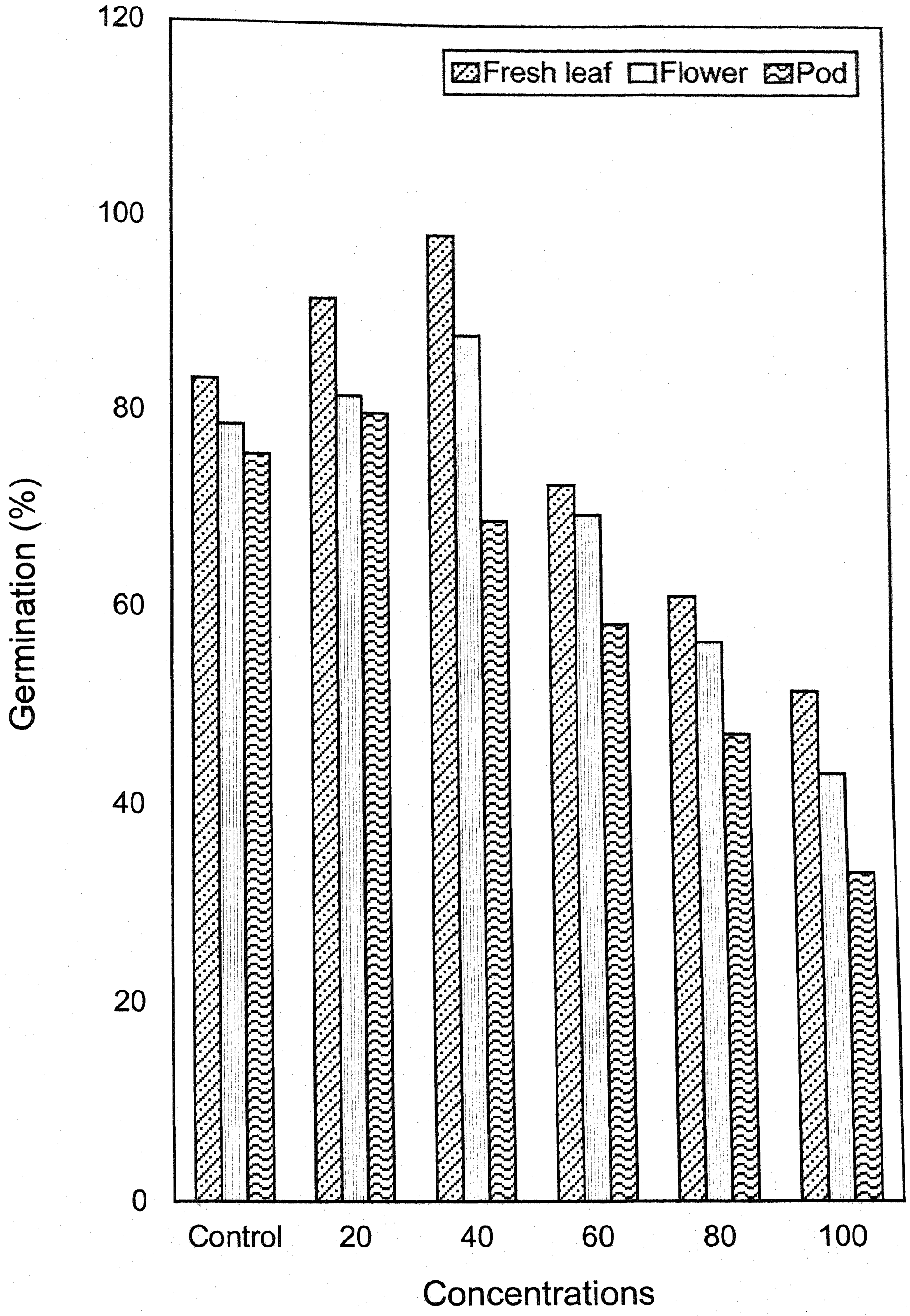


Fig.-2 : Effect of extract of *L. leucocephala* fresh leaf, flower and pod on the seed germination in *T.aestivum*

Table - 4 : Effect of flower extract of *Leucaena leucocephala* on the shoot and root in *Triticum aestivum* under laboratory conditions

Treatments	Control	20	40	60	80	100	CD (.05)
Fresh weight (g)							
Shoot	0.885	0.945	1.041	0.702	0.373	0.273	0.275
Root	0.502	0.686	0.890	0.412	0.196	0.188	0.241
Seedling	1.387	1.631	1.931	1.114	0.569	0.461	0.413
Dry weight (g)							
Shoot	0.347 (39.209)	0.400 (42.328)	0.474 (45.533)	0.304 (43.305)	0.170 (45.576)	0.136 (49.817)	N.S
Root	0.224 (44.622)	0.272 (39.650)	0.419 (47.079)	0.209 (50.728)	0.092 (46.939)	0.088 (46.809)	N.S.
Seedling	0.571 (41.168)	0.672 (41.202)	0.893 (46.245)	0.513 (46.050)	0.262 (46.046)	0.224 (48.590)	0.214
Moisture Content (g)							
Shoot	0.538 (60.791)	0.545 (57.672)	0.567 (54.467)	0.398 (56.695)	0.203 (54.424)	0.137 (50.183)	N.S.
Root	0.278 (31.412)	0.414 (43.810)	0.471 (45.245)	0.203 (28.917)	0.104 (27.882)	0.100 (36.630)	N.S.
Seedling	0.816 (58.832)	0.959 (58.798)	1.038 (53.755)	0.601 (53.950)	0.307 (53.954)	0.237 (51.410)	0.201

Value in parenthesis indicates percentage

2.312 g) over control. This attribute was adversely affected at 60-100% concentrations (Table-4) in *T. aestivum* and minimum values were observed at 100%. Similar trend was observed in case of entire seedling of *T. aestivum* (Table-4). The dry matter production in shoot and root was significantly enhanced by pretreatment of aqueous extract of flowers at 40% concentration and reduced at 60-100% with a maximum reduction at 100% concentration (Table-4).

Pretreatment of aqueous extract of pod had no significant effect on seed germination at 20% concentration, apparently increase at 40%. However, the value over control were not significant thereafter this treatment reduce the seed germination progressively with the increase concentration. The seedling growth in terms of shoot and root length was only promoted at 20% (22.8 cm) which was significantly higher over all other treatments and thereafter reduced at all the concentrations (Table-5) in *T.aestivum* and minimum value was observed for 100 % concentration. It is evident from the data presented in Table-5 that the shoot and root growth was more severely affected then as compared to the effect of leaves and flowers extracts.

Table 5: Effect of pod extract of *Leucaena leucocephala* on the shoot and root in *Triticum aestivum* under laboratory conditions

Treatment	Shoot length(cm)	Root length(cm)	Seedling elongation (cm)	Shoot Root ratio
Control	10.5	8.7	19.2	1.20:1
20	12.8	10	22.8	1.28 :1
40	9.8	8.1	17.9	1.20:1
60	7.6	6.5	14.1	1.16:1
80	5	4.4	9.4	1.13:1
100	3.2	2.9	6.1	1.10:1
C.D. (.05)	2.7	2.4	2.7	N.S.

The data presented in table -6 indicated that the fresh weight of shoot was significantly lower at 100% concentration (0.331g),which differs significantly from other treatments, where as maximum value was recorded at 20% (0.828g) which was statistically at par with control. This treatment caused similar effect on the fresh weight of root as well as of entire seedling, which was maximum in 20% concentration and there after reduced in progressive manner (Table-6) in *T. aestivum*. Pretreatment of aqueous extract of pods did not affect dry weight in shoot significantly at 20% concentration and caused reduction at 40-100% concentration. It is quite interesting to report that the dry weight in root was boosted by the pretreatment at 20% concentration and thereafter, decreased in a descending order. The total dry weight of seedling exhibited the similar trend to that of the root (Table -6). The moisture content in shoot, root and entire seedling showed difference only at lower concentration (20%) but was not statistically different and decreased further in all the concentrations of pod extract in *T. aestivum* (Table -6).

Table- 6: Effect of pod extract of *Leucaena leucocephala* on *Triticum aestivum* under laboratory conditions

Treatments	Control	20	40	60	80	100	CD (.05)
Fresh weight (g)							
Shoot	0.708	0.828	0.691	0.423	0.243	0.197	0.215
Root	0.496	0.511	0.494	0.363	0.178	0.134	0.276
Seedling	1.204	1.339	1.185	0.786	0.421	0.331	0.391
Dry weight (g)							
Shoot	0.205 (28.955)	0.227 (27.415)	0.172 (24.891)	0.093 (21.986)	0.079 (32.510)	0.068 (34.518)	N.S.
Root	0.126 (25.403)	0.155 (30.333)	0.080 (16.194)	0.070 (19.284)	0.033 (18.539)	0.029 (21.642)	N.S.
Seeding	0.331 (27.492)	0.382 (28.529)	0.252 (21.266)	0.163 (20.738)	0.112 (26.603)	0.097 (29.305)	N.S.
Moisture Content (g)							
Shoot	0.503 (71.045)	0.604 (72.585)	0.519 (75.109)	0.330 (78.014)	0.164 (67.490)	0.129 (65.482)	N.S.
Root	0.370 (74.597)	0.356 (69.667)	0.414 (83.806)	0.293 (80.716)	0.145 (81.461)	0.105 (78.358)	N.S.
Seedling	0.873 (72.508)	0.957 (71.471)	0.933 (78.734)	0.623 (79.262)	0.309 (73.397)	0.234 (70.695)	N.S.

Value in parenthesis indicates percentage

In another experiment, effect of decomposed leaf extract was determined on the germination and growth of *T. aestivum* in which the pretreatment extract significantly stimulated seed germination at 40% (96.33%), had no significant effect at 20 and 60% and reduced drastically at 80 - 100% concentration. The shoot length was increased by the treatment at lower concentration (20-40 %) and maximum was recorded at 40% which differs statistically from all other treatments and reduced at higher concentration (60-100 %). Similar spectrum of effect was noted in case of root length. It is evident from the table -7 that root growth was more severely affected at higher concentration than that of shoot.

Table 7 : Effect of Decomposed leaf extract of *Leucaena leucocephala* on *Triticum aestivum* germinability and growth

Treatment	Germination %	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot-Root ratio
Control	81.33	13.90	10.40	24.30	1.34:1
20 %	88.66	16.50	12.30	28.80	1.34:1
40 %	96.33	18.80	14.60	33.40	1.29:1
60 %	79.33	12.00	9.10	21.10	1.31:1
80 %	61.66	8.70	5.90	14.60	1.47:1
100 %	57.66	6.10	3.80	9.90	1.61:1
C.D. (.05)	15.31	3.71	2.81	4.10	N.S.

The influence of decomposed leaf extract revealed that the maximum value of fresh weight for shoot was obtained at 40% (1.285g) and minimum at 100% (0.407g) as shown in table -8. The fresh weight in root was only enhanced at 40%, decreased at 60 - 100% concentrations and insignificantly affected at 20 % concentration (Table -8). The fresh weight of the entire seedling was significantly boosted at

Table - 8: Effect of decomposed leaf extract of *Leucaena leucocephala* on seedling in *Triticum aestivum*

Treatments	Control	20	40	60	80	100	CD (.05)
Fresh weight (g)							
Shoot	0.967	1.102	1.285	0.959	0.582	0.407	0.191
Root	0.849	0.836	1.118	0.602	0.401	0.324	2.160
Seedling	1.816	1.938	2.403	1.561	0.983	0.731	0.314
Dry weight (g)							
Shoot	0.329 (34.023)	0.340 (30.853)	0.410 (31.907)	0.285 (29.718)	0.124 (21.306)	0.093 (22.850)	1.320
Root	0.168 (19.788)	0.183 (21.890)	0.221 (19.767)	0.127 (21.096)	0.102 (25.436)	0.066 (20.370)	N.S.
Seeding	0.497 (27.368)	0.523 (26.987)	0.631 (26.259)	0.412 (26.393)	0.226 (22.991)	0.159 (21.751)	2.310
Moisture Content (g)							
Shoot	0.638 (65.977)	0.762 (69.147)	0.875 (68.093)	0.674 (70.282)	0.458 (78.694)	0.314 (77.150)	N.S.
Root	0.681 (80.212)	0.653 (78.110)	0.897 (80.233)	0.475 (78.904)	0.299 (74.564)	0.258 (79.630)	N.S.
Seedling	1.319 (72.632)	1.415 (73.013)	1.772 (73.741)	1.149 (73.607)	0.757 (77.009)	0.572 (78.249)	N.S.

Value in parenthesis indicates percentage

40% concentration which was significantly superior over all other treatments and thereafter, reduced at all the used concentrations. The treatment reduced dry matter production at all the used concentrations except at 20% and 40% concentrations where, the increase was not significantly over control (Table -8). The treatment significantly enhanced dry matter in seedling at lower concentrations i.e. 20 and 40% and reduced at higher concentrations (Table - 8).

The moisture content were found higher over control up to a concentration of 60% and lower at 80 and 100% concentration in case of shoot (Table - 8). This attribute in case of root was found higher only at 40% concentration.

The results obtained on the influence of fresh leaf , flower, pods and decomposed leaf extract on germination and seedling growth of *T. aestivum* exhibited that lower concentrations were stimulatory in nature where as concentration of 60% and higher reduced the germination and growth.

The same experiments were repeated to study the allelopathic influence of *L. leucocephala* on *G. max*. The influence of fresh leaf extract resulted in promotion of seed germination at 20 and 40% and affected this attribute adversely at 60-100% concentration. The maximum value of 9.87cm. for shoot growth was recorded at 40% concentration followed by 20% (8.57cm) and the minimum value was observed at 100% (3.95) which was significantly lower compared to all other treatments (Table -9). The trend for root length and seedling elongation was similar to shoot length, where as shoot : root ratio was maximum at control and minimum at 100%. This shows that the treatment affected shoot growth more severely than root in *G. max*.

Table 9 :Effect of fresh leaf extract of *Leucaena leucocephala* on the shoot and root in *Glycine max* under laboratory conditions

Treatment	Shoot length (cm)	Root length (cm)	Seedling Elongation (cm)	Shoot Root ratio
Control	7.41	4.35	11.76	1.70:1
20	8.57	5.1	13.67	1.68:1
40	9.87	6.01	15.88	1.64:1
60	7.25	4.5	11.75	1.62:1
80	5	3.38	8.38	1.47:1
100	3.95	2.88	6.83	1.37:1
C.D. (.05)	1.23	1.61	3.12	N.S.

The fresh weight of shoot, root and entire seeding was significantly enhanced by the pretreatment up to 40 % concentration(1.023, 0.709, 1.732 g) and decreased at 60 -100 % concentrations in *G. max* (Table -10) as compared to control. Similar tendency was recorded for dry matter production in shoot, root and seedling of *G. max* (Table -10) but the effect on root dry weight was insignificant. The moisture content in shoot, root and seedling were significantly affected positively at 40% concentration and exhibited negative trend at higher concentrations (Table -10) in *G. max* which was minimum at 100% (0.302, 0.251, 0.553g).

The extract of flowers of *L. leucocephala* had no significant effect at 20%, increased significantly at 40%, and there after reduced significantly at higher concentrations. The reduction in seed germination at higher concentration (60-100%) was found proportional to the increase in concentration. Pretreatment of extract of flowers

Table - 10: Effect of fresh leaf extract of *Leucaena leucocephala* on *Glycine max*

Treatments	Control	20	40	60	80	100	CD(.05)
Fresh weight (g)							
Shoot	0.599	0.735	1.023	0.443	0.401	0.357	2.310
Root	0.498	0.695	0.709	0.398	0.302	0.284	2.810
Seedling	1.097	1.430	1.732	0.841	0.703	0.641	4.350
Dry weight (g)							
Shoot	0.155 (25.876)	0.177 (24.082)	0.267 (26.100)	0.093 (20.993)	0.061 (15.212)	0.055 (15.406)	0.810
Root	0.104 (20.884)	0.158 (22.734)	0.168 (23.695)	0.070 (17.588)	0.041 (13.576)	0.033 (11.620)	N.S.
Seeding	0.259 (23.610)	0.335 (23.427)	0.435 (25.115)	0.163 (19.382)	0.102 (14.509)	0.088 (13.729)	1.310
Moisture Content (g)							
Shoot	0.445 (74.124)	0.558 (75.918)	0.756 (73.900)	0.350 (79.007)	0.340 (84.788)	0.302 (84.594)	2.120
Root	0.394 (79.116)	0.537 (77.266)	0.541 (76.305)	0.328 (82.412)	0.261 (86.424)	0.251 (88.380)	N.S.
Seedling	0.839 (76.390)	10.960 (76.573)	1.297 (74.885)	0.678 (80.618)	0.601 (85.491)	0.553 (86.271)	2.810

Value in parenthesis indicates percentage

significantly accelerated the shoot length up to a concentration of 40 %, and recorded a maximum value of 9.03 cm and was reduced significantly at 80 and 100 % concentrations with a value of 3.35 cm only (Table - 11) in *G. max* over control (6.51 cm). The length of root was promoted at 20 and 40 %, not affected significantly at 60% and suppressed at 80 and 100% concentrations (Table -11) in *G. max*.

Table 11: Effect of flower extract on *Glycine max* growth under laboratory conditions

Treatment	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot-Root ratio
Control	6.51	4.1	10.61	1.59 :1
20	7.91	4.81	12.72	1.64 :1
40	9.03	5.73	14.76	1.58 :1
60	6.1	3.98	10.08	1.53 :1
80	4.27	2.81	7.08	1.52 :1
100	3.35	2.31	5.66	1.45 :1
C.D. (.05)	1.91	1.61	2.78	N.S.

The seedling elongation exhibiting similar trend was stimulated at lower concentration with maximum effect at 40% (14.76 cm) and reduced at higher concentration in *G. max*. The shoot -root ratio was progressively reduced with increased concentrations but values were statistically not significant over control.

The fresh weight of shoot and root was boosted by pretreatment up to 40 %, did not affect, at 60% and reduced at 80-100% concentration. However, the fresh weight in seedling was enhanced at 20 and 40% concentrations and gradually decreased with increased concentrations (Table -12), but was significantly higher only at 40%

Table - 12 : Effect of flower extract of *Leucaena leucocephala* of seedling on *Glycine max*

Treatments	Control	20	40	60	80	100	CD(.05)
Fresh weight (g)							
Shoot	0.547	0.610	0.892	0.425	0.334	0.301	0.301
Root	0.343	0.495	0.649	0.329	0.296	0.218	0.161
Seedling	0.890	1.105	1.541	0.754	0.630	0.519	0.561
Dry weight (g)							
Shoot	0.115 (21.024)	0.162 (26.557)	0.246 (27.578)	0.093 (21.882)	0.052 (15.569)	0.037 (12.292)	0.910
Root	0.098 (28.571)	0.108 (21.818)	0.152 (23.421)	0.069 (20.973)	0.038 (12.838)	0.028 (12.844)	N.S.
Seeding	0.213 (23.933)	0.270 (24.434)	0.398 (25.827)	0.162 (21.485)	0.090 (14.286)	0.065 (12.524)	0.103
Moisture Content (g)							
Shoot	0.432 (78.976)	0.448 (73.443)	0.646 (72.422)	0.332 (78.118)	0.282 (84.431)	0.260 (87.708)	0.216
Root	0.245 (71.429)	0.387 (78.182)	0.497 (76.579)	0.260 (79.027)	0.258 (87.162)	0.190 (87.156)	N.S.
Seedling	0.677 (76.067)	0.835 (75.566)	1.143 (74.173)	0.592 (78.515)	0.540 (85.714)	0.450 (87.476)	0.413

Value in parenthesis indicates percentage

concentration over the control. The dry matter in shoot and seedling was found significantly higher at 40% concentration and reverse was observed for higher concentrations in *G. max*. (Table -12) where as values for root dry weight were statistically at par with control. The moisture content in shoot was not affected at 20% concentration, increased at 40% and thereafter reduce progressively in case of root this attribute was promoted at 20 and 40% concentrations and suppressed at 60-100% concentration. Similar spectrum in term of moisture content in seedling was observed in *G. max*. (Table -12).

The aqueous extract of pods of *L. leucocephala* was tested to determined its effect on seed germination in *G. max* (Table -13). The pretreatment of pod extract did not affect the seed germination at 20% and reduced this attribute at all the concentration i.e.40-100%.

The shoot and root length was promoted at 20% concentration (6.73 and 4.61 cm) over control (6.30 and 4.34 cm) but was statistically at par and reduced progressively with the increased concentrations in *G. max* and was minimum at 100 % concentration (2.95 and 2.13 cm) which differs significantly from control. The shoot- root ratio decreased gradually with increasing concentration of the extract in *G. Max* but does not differ significantly.

Table 13: Effect of pod extract on *Glycine max* under laboratory conditions

Treatment	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot Root ratio
Control	6.30	4.34	10.64	1.45:1
20	6.73	4.61	11.34	1.46 :1
40	5.85	3.81	9.66	1.54 :1
60	4.55	3.10	7.65	1.47 :1
80	3.85	2.68	6.53	1.44 :1
100	2.95	2.13	5.08	1.39 :1
C.D. (.05)	1.18	0.81	1.81	N.S.

The effect of pod extract of *L. leucocephala* on the fresh weight of shoot, root and seedling exhibited that at 20% concentration the values were maximum (0.555, 0.430 and 0.985g) which were not significantly different from control (Table -14) but, thereafter reduced gradually with minimum values at 100 % concentration (0.196, 0.098 and 0.294 g). The dry matter production was enhanced in shoot, root and seedlings only at 20% concentration over control and reduced at higher concentrations. The pre treatment of pod extract did not affect moisture content at lower concentrations and reduced it at higher concentrations in shoot, root and seedling but the effects were insignificant for moisture content of *G. max*.(Table -14).

Table - 14: Effect of pod extract of *Leucaena leucocephala* of seedling on *Glycine max*

Treatments	Control	20	40	60	80	100	CD (.05)
Fresh weight (g)							
Shoot	0.538	0.555	0.486	0.37	0.350	0.196	0.118
Root	0.382	0.430	0.326	0.25	0.12	0.098	0.810
Seedling	0.920	0.985	0.812	0.61	0.47	0.294	2.130
Dry weight (g)							
Shoot	0.156 (28.996)	0.162 (29.189)	0.106 (21.811)	0.073 (20.000)	0.057 (16.239)	0.026 (13.265)	0.103
Root	0.097 (25.393)	0.108 (25.116)	0.063 (19.325)	0.036 (14.575)	0.012 (10.084)	0.032 (32.653)	N.S.
Seeding	0.253 (27.500)	0.274 (28.395)	0.167 (20.567)	0.109 (17.810)	0.069 (14.681)	0.058 (19.728)	0.171
Moisture Content (g)							
Shoot	0.382 (71.004)	0.393 (70.811)	0.380 (78.189)	0.292 (80.000)	0.214 (60.969)	0.169 (86.224)	N.S.
Root	0.285 (74.607)	0.322 (74.884)	0.263 (80.675)	0.211 (85.425)	0.107 (89.916)	0.066 (67.347)	N.S.
Seedling	0.667 (72.500)	0.696 (71.605)	0.645 (79.434)	0.503 (82.190)	0.321 (68.298)	0.235 (79.932)	N.S.

Value in parenthesis indicates percentage

The data pertaining to influence of decomposed leaf extract on *G. max* is presented in table -15, which indicate that extract of decomposed leaf of *L. leucocephala* accelerated seed germination at lower concentration with maximum at 40% (79.66%) which was not statistically different from 20% concentration(77.33%) and retarded at higher concentration (51.33% at 100%). The length of shoot and root were promoted at 20 and 40% concentration and reduced at 60-100% concentrations in *G. max*.

The reduction was found more profound in case of shoot then root (Table -15). The shoot- root ratio decreased gradually with increasing concentrations of the extract in *G. max*, with the maximum value at control but the results were insignificant (Table- 15).

Table 15: Effect of Decomposed leaf extract of *Leucaena leucocephala* on *Glycine max* germinability and growth

Treatment	Germination %	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot- root ratio
Control	71.33	7.48	4.39	11.87	1.70 :1
20 %	77.33	8.87	5.35	14.22	1.65 :1
40 %	79.66	10.55	6.76	17.31	1.56 :1
60 %	64.66	6.5	4.25	10.75	1.52 :1
80 %	61.33	5.21	3.56	8.77	1.46 :1
100 %	51.33	4.29	3.11	7.4	1.37 :1
C.D.(.05)	13.33	3.21	2.09	3.95	N.S.

The treatment with extract of decomposed leaf extract of *L. leucocephala* (Table -16) caused increment in fresh weight of shoot,

Table - 16: Effect of decomposed leaf extract of *Leucaena leucocephala* of seedling on *Glycine max*

Treatments	Control	20	40	60	80	100	CD
Fresh weight (g)							
Shoot	0.621	0.781	1.104	0.492	0.452	0.391	0.291
Root	0.532	0.728	0.773	0.429	0.334	0.302	0.187
Seedling	1.153	1.509	1.877	0.921	0.786	0.693	0.219
Dry weight (g)							
Shoot	0.172 (27.697)	0.191 (24.456)	0.281 (25.453)	0.118 (23.984)	0.079 (17.478)	0.069 (17.647)	0.103
Root	0.121 (22.744)	0.169 (23.214)	0.182 (23.545)	0.092 (21.445)	0.059 (17.665)	0.042 (13.907)	N.S.
Seedling	0.293 (25.412)	0.360 (23.857)	0.463 (24.667)	0.210 (22.801)	0.138 (17.557)	0.111 (16.017)	0.119
Moisture Content (g)							
Shoot	0.449 (72.303)	0.590 (75.544)	0.823 (74.547)	0.374 (76.016)	0.373 (82.522)	0.322 (82.353)	N.S.
Root	0.411 (77.256)	0.559 (76.786)	0.591 (76.455)	0.337 (78.555)	0.275 (82.335)	0.260 (86.093)	N.S.
Seedling	0.860 (74.588)	1.149 (76.143)	1.414 (75.333)	0.711 (77.199)	0.648 (82.443)	0.582 (83.983)	N.S.

Value in parenthesis indicates percentage

root and seedlings up to a concentration of 40% and reduced this attribute at higher concentrations. The reduction in fresh weight at higher concentration was found proportional to the concentration (Table-16). The dry matter in shoot, root and seedling was significantly higher at 20-40% concentration and reduced at 60-100% concentration of the extract in *G. max*.(Table -16).The moisture content in shoot, root and seedling non significantly increased and decreased at lower (20-40%) and higher (60-100%) concentrations, respectively over the control(Table -16).

Allelopathic influence under nursery conditions :

The allelopathic effect was studied under nursery conditions. The experiment involved the soil collected beneath the *Leucaena* plantation in combination with field soil. The *Leucaena* soil was mixed at four level

100% *Leucaena* soil (1:0)

25% *Leucaena* soil + 75% field soil (1:3)

50% *Leucaena* soil + 50% field soil (1:1)

100% field soil (0:1)

Three kg of soil of each combination was filied in polythene bags. The data were recorded germination shoot, root, seed elongation and shoot -root ratio and presented in table -17. The data revealed that the seed germination was reduced by *Leucaena* soil in all the combinations over control. The maximum seed germination (84.33%) was recorded for 1: 3 ratio which was at par with field soil treatment. The minimum germination was observed in 100% Leucaena soil (51.66%). The length of shoot inhibited gradually, after reaching

maximum (21.35cm) at 1:3 ratio, with increase in amount of *Leucaena* soil and minimum shoot length was recorded in *Leucaena* soil only (Table-17) in *T. aestivum* (11.35cm.). The root length showed similar trends but it was affected more adversely then shoot. The treatment influenced the seedling elongation as in shoot and root in *T.aestivum* (Table-17). The treatment gradually increased shoot-root ratio with increase in amount of *Leucaena* soil.

Table :17 Effect of soil collected from *Leucaena leucocephala* field under nursery conditions on *Triticum aestivum* germination and growth

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot Root ratio
0 : 100	76.33	16.50	15.40	31.90	1.07:1
25 : 75	84.33	21.35	17.95	39.30	1.19:1
50 : 50	72.33	13.75	11.60	25.35	1.19:1
100 : 0	51.66	11.35	9.10	20.45	1.25:1
C.D. (.05)	9.13	4.81	3.16	6.15	N.S.

Treatment : Soil beneath Leucaena plantation : field soil

The fresh weight of shoot and root was only enhanced in a mixture of 25% *Leucaena* soil + 75% field soil (1.623g), while other combination reduced this attribute both in shoot and root (Table-18). The fresh weight of seedling exhibited the same trend of effect in *T.aestivum* (Table -18).

Table :18 Effect of soil collected from *Leucaena leucocephala* field under nursery conditions on *Triticum aestivum* seedling productivity

Treatments	Soil beneath Leucaena : Field soil				
	0 : 100	25 : 75	50 : 50	100 : 0	C.D.(.05)
Fresh weight (g)					
Shoot	1.325	1.632	0.915	0.718	0.216
Root	1.098	1.213	0.613	0.412	0.271
Seedling	2.423	2.845	1.528	1.130	0.516
Dry weight (g)					
Shoot	0.524 (39.547)	0.615 (37.684)	0.389 (42.514)	0.285 (39.694)	0.189
Root	0.231 (21.038)	0.267 (22.012)	0.154 (25.122)	0.117 (28.398)	N.S.
Seedling	0.755 (31.160)	0.882 (31.002)	0.543 (35.537)	0.402 (35.575)	0.213
Moisture Content (g)					
Shoot	0.801 (60.453)	1.017 (62.316)	0.526 (57.486)	0.433 (60.306)	0.316
Root	0.867 (78.962)	0.946 (77.988)	0.459 (74.878)	0.295 (71.602)	0.401
Seedling	1.668 (68.840)	1.963 (68.998)	0.985 (64.463)	0.728 (64.425)	0.761

Value in parenthesis represents percentage

The soil combination treatments decreased dry weight in shoot, root and seedling in all the combination except 25% of *Leucaena* soil + 75% field soil, where the effect was found positive (Table -18) in *T. aestivum*. The moisture contents in shoot, root and seedling in terms of weight was promoted at 25% of *Leucaena* soil + 75% field soil and reduced in other combination . However, the percentage of moisture in

shoot, root and seedling was not affected in any of the combination.

The seed germination in *G. max* was severely affected due to *Leucaena* soil (Table -19) as compared to *T. aestivum*. The minimum 54.33% germination was recorded in *Leucaena* soil, while this germination per cent was 77.66% in field soil, both the treatments differ significantly. The shoot, root and seedling elongation followed the same trend and maximum values were recorded 1: 3 ratio and minimum at 100% *Leucaena* soil in *G. max*. (Table -19). The shoot - root ratio was not affected significantly by the combination of *Leucaena* soil in *G. max* (Table -19).

Table :19 Effect of soil collected from *Leucaena leucocephala* field under nursery conditions on *Glycine max* germination and growth

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling elongation (cm)	Shoot Root ratio
0 : 100	73.66	7.79	4.41	12.2	1.766 :1
25 : 75	77.33	8.95	4.98	13.93	1.797 :1
50 : 50	61.66	6.53	3.85	10.38	1.696 :1
100 : 0	54.33	5.13	3.52	8.65	1.457 :1
C.D. (.05)	7.13	1.48	N.S.	2.11	N.S.

Treatment : Soil beneath Leucaena plantation : Field soil

The seedling growth in terms of fresh weight of shoot and root was not significantly stimulated by the treatments but maximum values were observed at 1: 3 ratio, where as seedling was significantly stimulated in a combination of 25% of *Leucaena* soil + 75% field soil while other combination reduced this attribute in *G. max* (Table-20).

Table :20 Effect of soil collected from *Leucaena leucocephala* field under nursery conditions on *Glycine max* seedling

Treatment	Soil beneath Leucaena : Field soil				
	0 : 100	25 : 75	50 : 50	100 : 0	C.D.(.05)
Fresh weight (g)					
Shoot	0.643	0.789	0.621	0.451	N.S.
Root	0.539	0.759	0.491	0.356	N.S.
Seedling	1.182	1.548	1.112	0.807	0.316
Dry weight (g)					
Shoot	0.181 (28.149)	0.198 (25.095)	0.162 (26.087)	0.106 (23.503)	N.S.
Root	0.129 (23.933)	0.178 (23.452)	0.142 (28.921)	0.081 (22.753)	N.S.
Seedling	0.310 (26.227)	0.376 (24.289)	0.304 (27.338)	0.187 (23.172)	N.S.
Moisture Content (g)					
Shoot	0.462 (71.851)	0.591 (74.905)	0.459 (73.913)	0.345 (76.497)	N.S.
Root	0.410 (76.067)	0.581 (76.548)	0.349 (71.079)	0.275 (77.247)	N.S.
Seedling	0.872 (73.773)	1.172 (75.711)	0.808 (72.662)	0.620 (76.828)	N.S.

The dry matter in shoot was enhanced by the 25% *Leucaena* soil combination and suppressed at higher levels of *Leucaena* soil. The dry matter in root increased in 25% and 50% combination of *Leucaena* soil and drastically reduced in *Leucaena* soil only (Table -20) in *G.*

max. *Leucaena* soil promoted moisture contents in shoot, root and seedling at 25% of *Leucaena* soil and reduced it in 50 and 100% *Leucaena* soil over control field soil. The dry weight and moisture contents values did not differ significantly under all the treatments.

Allelopathic studies under field conditions :

Allelopathic influence of *L. leucocephala* under field condition was determined on *G. max* during 1997-99. The plant population per meter row was reduced under *L. leucocephala*. The decline in plant population was compensated to some extend due to pruning of tree component and maximum plant population(5.98) was registered in crop subjected to mulch(Table-21) which is statistically at par with control(5.65) but differs significantly from other treatments. The observation of two years revealed more significant effect between the years pertain to plant population of *G. max*. The plant height of soybean was significantly reduced by *L. leucocephala*. The reduction in plant height was significantly curtailed due to pruning of tree. The height of plant was significantly higher over tree + crop, crop in association with *Leucaena* and crop with *Leucaena's* tree pruned. The maximum plant height (71.85cm) was recorded in crop applied with mulch which differs significantly from minimum value recorded with Tree + Crop (52.0cm.).This growth parameter showed significant difference between the two years (Table-21).

Table 21: Effect of *Leucaena leucocephala* on the plant population and height of *Glycine max*

Treatment	Growth attributes			
	Plant population (m/row)		Plant height (cm)	
	1997-98	1998-99	1997-98	1998-99
Sole Crop	5.65	5.08	66	62.8
Tree + Crop	4.4	4.2	52	50.05
Tree + Pruned + Crop	4.95	4.54	57	52.27
Tree + Pruned + Mulch + Crop	5.2	5	62	59.34
Crop+ Mulch	5.98	5.25	71.85	65
C.D.(.05)	0.39	0.24	7.03	4.11

The data for the number of branches per plant significantly reduced due to *L. leucocephala* tree during both the years (Table-22). The number of branches per plant was maximum in the treatment, crop + mulch (11.0 and 11.5 branches/ plant) is followed by sole crop and minimum number of branches per plant were recorded in tree + crop (6.00 and 6.01 branches/ plant) in both the years (Table-22). Number of leaves exhibited the similar response to that of branches per plant, in the crop + mulch number of leaves were maximum (78.22and 73.34 branches/ plant) which is followed by sole crop (control). However, formation of leaves was accelerated due to mulch application over crop during both the years. A significant reduction in leaves was measured in the treatments tree + crop, tree + pruned + crop, tree + pruned + mulch + crop respectively over sole crop (Table-22).

Table 22: Effect of *Leucaena leucocephala* on the growth of *Glycine max*

Treatment	Growth attributes			
	Mean No.of branches/plant		Mean No.of leaf/plant	
	1997-98	1998-99	1997-98	1998-99
Sole Crop	10.67	10.21	64.1	63.05
Tree + Crop	6	6.01	42.27	40
Tree + Pruned + Crop	7.59	7.08	51.11	47.13
Tree + Pruned + Mulch + Crop	8	8.58	57.08	52.1
Crop+ Mulch	11	11.5	78.22	73.34
C.D.(.05)	1.89	2.11	11.13	12.11

Observation on quantitative flowering was made and accordingly the data presented in table-23. Quantitative flowering was significantly inhibited in association of *L. leucocephala*. The minimum number of flower (32.65/ plant) were recorded in *G. max* in association with tree. The production of flowers per plant was found higher (38.07/plant) in association of pruned tree of *L. leucocephala* as compared to unpruned trees +crop (32.65). The reduction in quantitative flowering was further curtailed down by adding mulch, though maximum number of flower (52.75) were produced on plant of soybean subjected to mulch treatment. However, the data was not found statistically significant over control. The quantitative flowering during 1998-99 exhibited the trend similar to that of 1997-98 but the adverse effect on this attributes was more profound in all the treatments (Table-23) compared to first year..

Table 23: Effect of *Leucaena leucocephala* on the mean number of flowers sand pods of *Glycine max*

Treatment	Growth attributes			
	Mean No. of flower/plant		Mean No.ofpods/plant	
	1997-98	1998-99	1997-98	1998-99
Sole Crop	50	38.6	38.1	33.6
Tree + Crop	32.65	30.8	29.7	27.05
Tree + Pruned + Crop	38.07	31.9	31	28.75
Tree + Pruned + Mulch + Crop	43.29	39.65	34 .00	33.15
Crop+ Mulch	52.75	44.6	40.5	37.58
C.D. (.05)	8.18	7.38	6.31	4.39

The pod - set was adversely affected only 29.70 pods were observed on plant of *G. max* in association of *L. leucocephala* against the 38.10 pods/plant in control plant (sole crop). The pruning treatment was found to counteract the adverse effect of *L. leucocephala* on pods-set. A non-significant promotion in pod-set over control was observed in plant subjected to mulch treatment during first year. The tree component had a more severe adverse effect on the pod set in *G. max* in the second year (Table-23). The maximum number of pods/plant were recorded in plants applied with mulch during both the years of experiment (Table-23).

The yield of *G. max* was not affected significantly due to treatments except in case of trees with crop (5.00q/ha), where a significant reduction was recorded (Table-24) during the first year over control (7.37q/ha). A significant reduction in yield was registered in all

the treatments viz tree + crop, tree pruned +crop, tree pruned + mulch +crop over sole crop (control). The seed yield remained unaffected in the treatment of crop + mulch as compared to sole crop (Table- 24). However, the test weight for the seed was not much affected due to any of the treatment in *G. max* (Table -24) except in tree + crop treatment.

Table 24: Effect of *Leucaena leucocephala* on the test weight of seeds and yield of *Glycine max*

Treatment	Yield parameters			
	Test weight (g)		Yield (q/ha)	
	1997-98	1998-99	1997-98	1998-99
Sole Crop	120.9	118	7.37	7
Tree + Crop	102.05	98.24	5	4.02
Tree + Pruned + Crop	110.18	105.37	5.92	5.6
Tree + Pruned + Mulch + Crop	119	113.15	6.27	5.97
Crop+ Mulch	124.28	115.74	7.67	7.2
C.D. (.05)	8.11	9.19	0.81	0.67

The similar set of experiment under field conditions was conducted for *T. aestivum,* which was taken as an intercrop with *L. leucocephala* during rabi season (winter) during 1997-99. The data were recorded for plant population per m row, plant height, number of total, effective and non-effective tillers, test weight and yield and presented in subsequent tables. The data presented in table - 25 revealed that plant population was not significantly influenced by the treatments except crop + tree (13.06 plant m/row), where a significant reduction over control (16.20 plant m/row) was recorded in *T.aestivum*

(Table -25) during the first year. The plant population was reduced during the second year in all the treatment including sole crop as compare to the first year (Table - 25). However, significant difference was recorded among the treatments as compared to sole crop. *L. leucocephala* suppressed the height of *T. aestivum* in its association. The suppression effect was counteracted when the trees were pruned (Table- 25). The mulch application apparently increased the plant height but the data were not found statistically significant during both the years. The data presented in table -25 revealed the similar spectrum of effect during the second year.

Table 25: Effect of *Leucaena leucocephala* on the plant population and height of *Triticum aestivum*

Treatment	Growth attributes			
	Plant population (m/row)		Plant height (cm)	
	1997-98	1998-99	1997-98	1998-99
Sole Crop	16.2	14.8	84.29	80.01
Tree + Crop	13.06	13	75.55	73.05
Tree + Pruned + Crop	14	13.8	79.16	76.68
Tree + Pruned + Mulch + Crop	15.1	14.3	81.12	79
Crop+ Mulch	17.05	16	85.68	83.04
C.D.(.05)	3.06	N.S.	6.11	7.09

The production of tillers was significantly reduced by *L. leucocephala* during both the years of experiment in wheat under tree + crop treatment over control and crop + mulch treatment (Table- 26).

The reduction imposed by the tree component was counteracted to some extend by pruning and further curtailed by addition of mulch and pruning together (Table -26). The tree component not only affect the formation of tillers but also their effectiveness in *T. aestivum* (Table - 26). The maximum and minimum number of effective tillers were recorded in the treatment crop + mulch (15.80 and 13.88) and tree + crop (6.00 and 4.00), respectively during the first year and second year too (Table -26). The maximum number of non effective tillers were produced in treatment of tree + crop and in other treatment the value were not significant during both the years.

Table 26: Effect of *Leucaena leucocephala* on the tillers in *Triticum aestivum*

Treatment	Growth attributes					
	Mean no. of tiller/plant		Mean no. of effective tiller/plant		Mean no. of non effective tiller/plant	
	1997-98	1998-99	1997-98	1998-99	1997-98	1998-99
Sole Crop	14.5	13	13.33	11.1	1.17	2.4
Tree + Crop	9.6	8.6	6	4	3.6	4.6
Tree + Pruned + Crop	10.4	9.89	8.2	6.28	2.2	3.61
Tree + Pruned + Mulch + Crop	13	11	10.6	8	2.4	3
Crop+ Mulch	17.8	15.06	15.8	13.88	2	2.12
C.D. (.05)	4.11	3.89	5.01	6.01	N.S.	N.S.

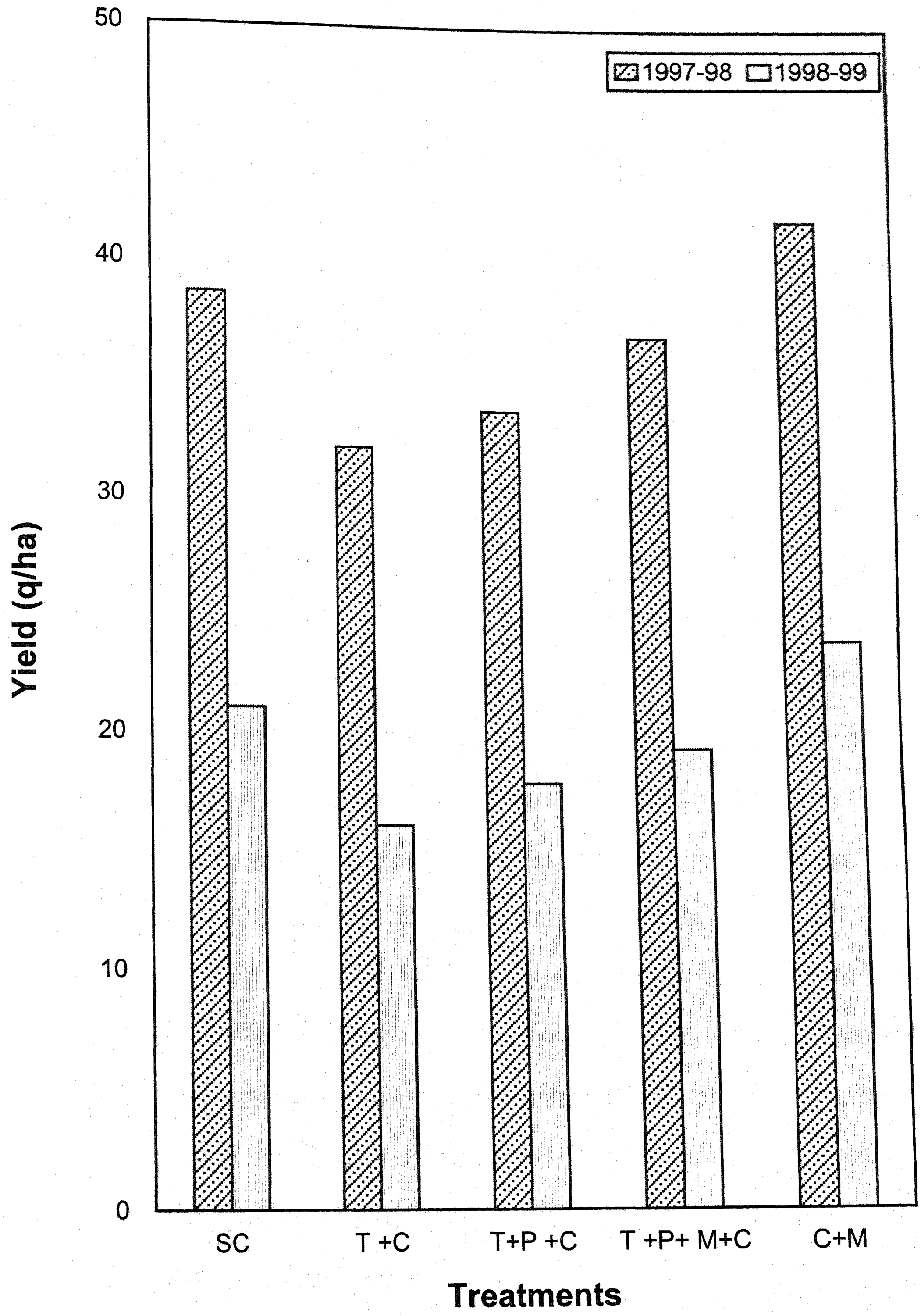
The data pertaining to test weight and straw yield (Table - 27) revealed that the maximum test weight was recorded under crop + mulch treatment under both the years (4.85 and 4.25 g) which was

statistically at par with control but differs significantly with tree + crop treatment (4.14 and 3.21 g). The over all test weight decreased in second year as compared to first year. The data for straw yield was recorded, the maximum values were observed for crop + mulch treatment (36.79 and 30.79q/ha, respectively for both the years) which did not differ statistically from sole crop treatment (33.36 and 27.50 q/ha, respectively for both the years) but differs significantly from tree + crop treatment. The mean test weight (4.47 and 3.75 g, respectively) and straw yield (30.93 and 25.62q/ha, respectively) values were more during first year as compared to second year.

Table 27: Effect of *Leucaena leucocephala* on the test weight of grains and yield of *Triticum aestivum*

Treatment	Yield parameters			
	Test weight 100 seeds (g)		Straw yield (q/ha)	
	1997-97	1998-99	1997-97	1998-99
Sole Crop	4.56	4	33.36	27.5
Tree + Crop	4.14	3.21	23.66	20.66
Tree + Pruned + Crop	4.32	3.53	29.5	23.5
Tree + Pruned + Mulch+ Crop	4.5	3.78	31.34	25.66
Crop+ Mulch	4.85	4.25	36.79	30.79
Mean	4.47	3.75	30.93	25.62
C.D. (.05)	N.S.	0.61	4.31	6.11

The data related to grain yield of *T. aestivum* during 1997- 98 and 1998-99 are presented in fig-3. The data indicates that maximum grain



SC = Sole crop; T = Tree; C= Crop; P = Pruning; M= Mulch

Fig - 3 : Effect of *L. leucocephala* on grain yield of *T. aestivum*

yield during both the years was recorded with treatment crop + mulch (41.74 and 23.85q/ha, respectively) followed by sole crop (38.57 and 21.04q/ha, respectively) which were significantly higher compared to tree + crop treatment (32.05and 16.06 q/ha, respectively), which recorded minimum yield both the years. The minimum yield recorded for tree+ crop may be due to the allelopathic influence of *L. leucocephala* on *T. aestivum*. The over all yield reduced during second year significantly compared to first year under all treatments.

Physiological parameter of companion crop

The canopy of *L. leucocephala* was found to affect the physiological parameters *viz.* leaf temperature, relative humidity, PAR and rate of transpiration of intercrop significantly.

L. leucocephala markedly reduce leaf temperature of *G. max*. The reduction in leaf temperature was cut down when *Leucaena* was subjected to pruning which become more distinct when mulch was added. All the treatments reduced leaf temperature and minimum leaf temperature was recorded for tree + crop combination (30.8^{0}C) and maximum for sole crop (36.7^{0}C). *Leucaena* canopy increased relative humidity at the leaf surface in all the treatment as compared to sole crop. However, the maximum value of relative humidity was registered in the treatment of *G. max* crop in association with unpruned tree (69.68%) whereas, minimum relative humidity was observed in sole crop (60.58%) as evident from fig -4.

Photo synthetically active radiation (PAR) was reduced in all the treatment with significant reduction in the treatment crop with

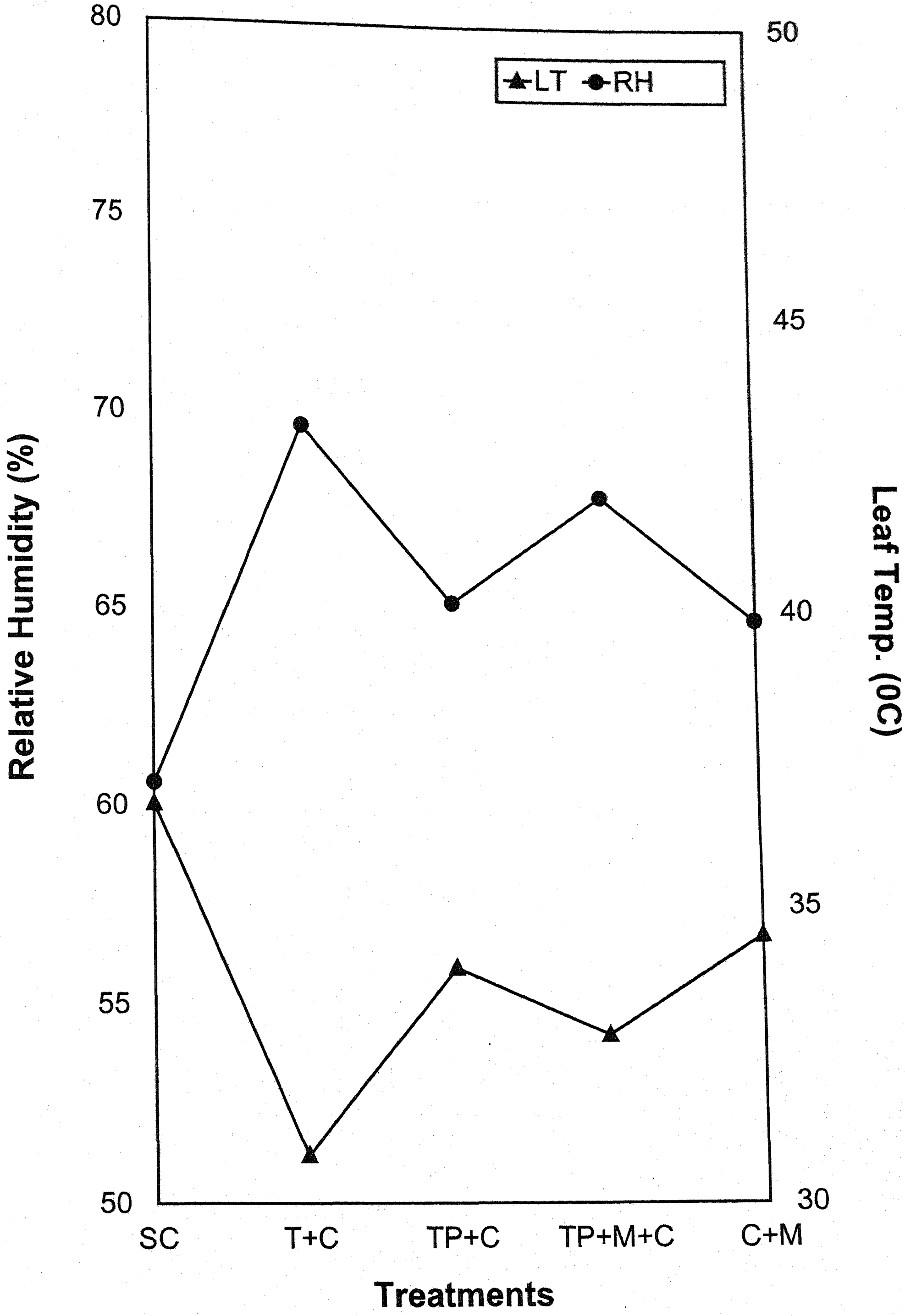


Fig. - 4 : Influence of *L. leucocephala* on leaf temperature and relative humidity in *G. max*

association unpruned tree (803.27 μ mole/ sec cm^2) over the sole crop (1420 μ mole/ sec cm^2) as reflected in fig. - 5. The rate of transpiration declined due to canopy of *L. leucocephala* and the maximum value for rate of transpiration was observed for tree+ crop (11.31$\mu g cm^{-2} s^{-1}$) whereas, minimum values were recorded for sole crop (7.21 $\mu g cm^{-2} s^{-1}$). This decline was counteracted by pruning. It is arpent that PAR and rate of transpiration were negatively co-related with tree canopy in this experiment therefore, the value of PAR and rate of transpiration decreased in the presence of tree canopy and increased due to absence of tree canopy or pruning of canopy(Fig.-5).

In Rabi season *T. aestivum* was grown as companion crop with *L. leucocephala*. The physiological parameters followed the same trend as was observed with *G. max*. The leaf temperature was significantly reduced in all the treatment except crop + mulch, where the values were not significantly affected as compared to control (Fig.-6).

Relative humidity at the leaf surface was significantly increased in wheat in association with *L. leucocephala*. This promotion was counteracted by pruning of trees. It is important to mention here that the value of relative humidity was significantly higher in wheat in the treatments where trees were pruned and mulch was applied (Fig-6). PAR at the crop surface was reduced by the introduction of tree component (*L. leucocephala*). This reduction was reversed to some extent by pruning treatment and this attribute was non-significantly affected in case of crop applied with mulch. The rate of transpiration in case of *T. aestivum* was reduced significantly in all the treatment with maximum reduction in *T. aestivum* grown with unpruned trees (Fig.-7).

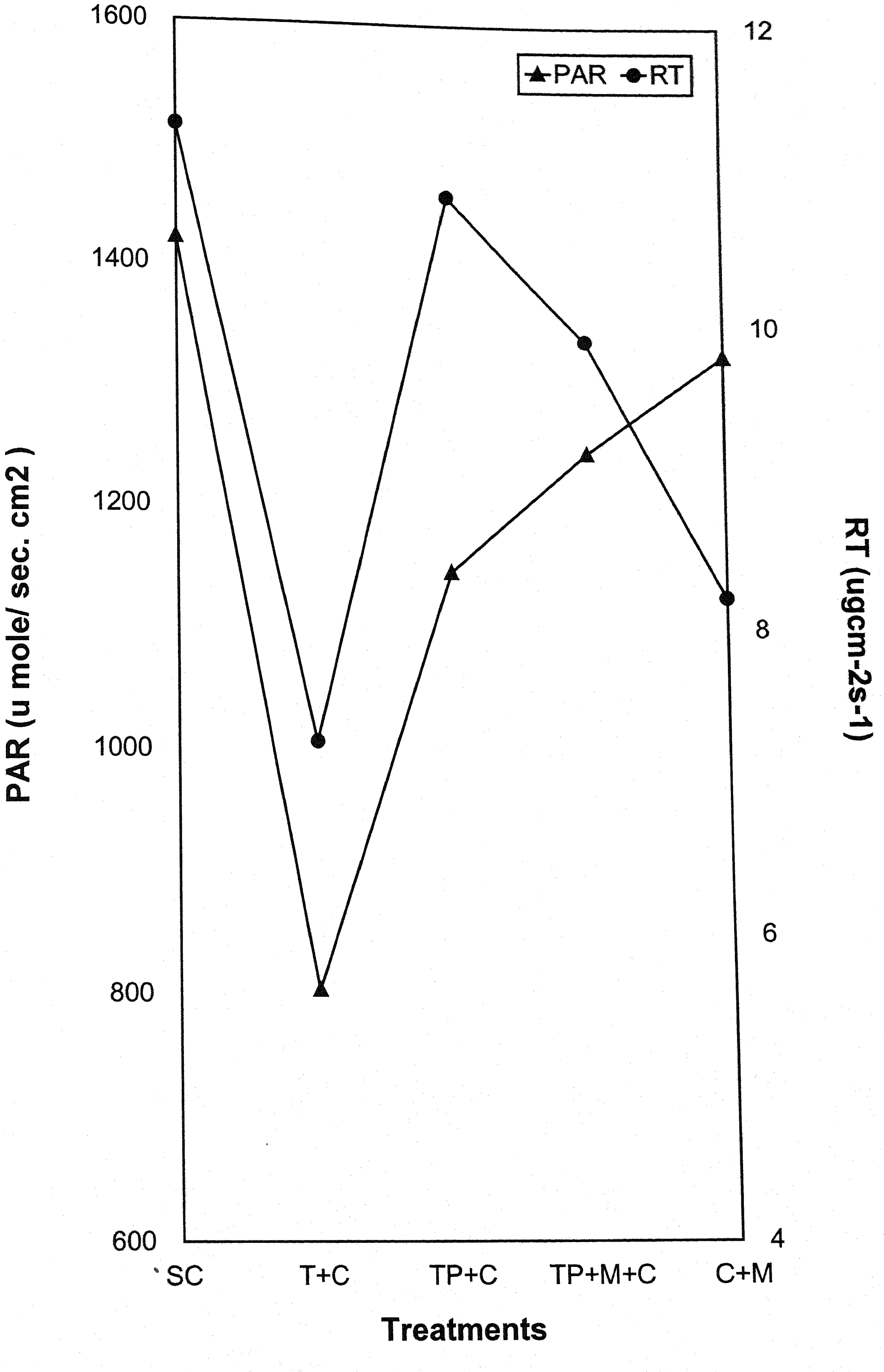


Fig.- 5:Influence of *L. leucocephala* on PAR Rate of Transpiration in *G. max*

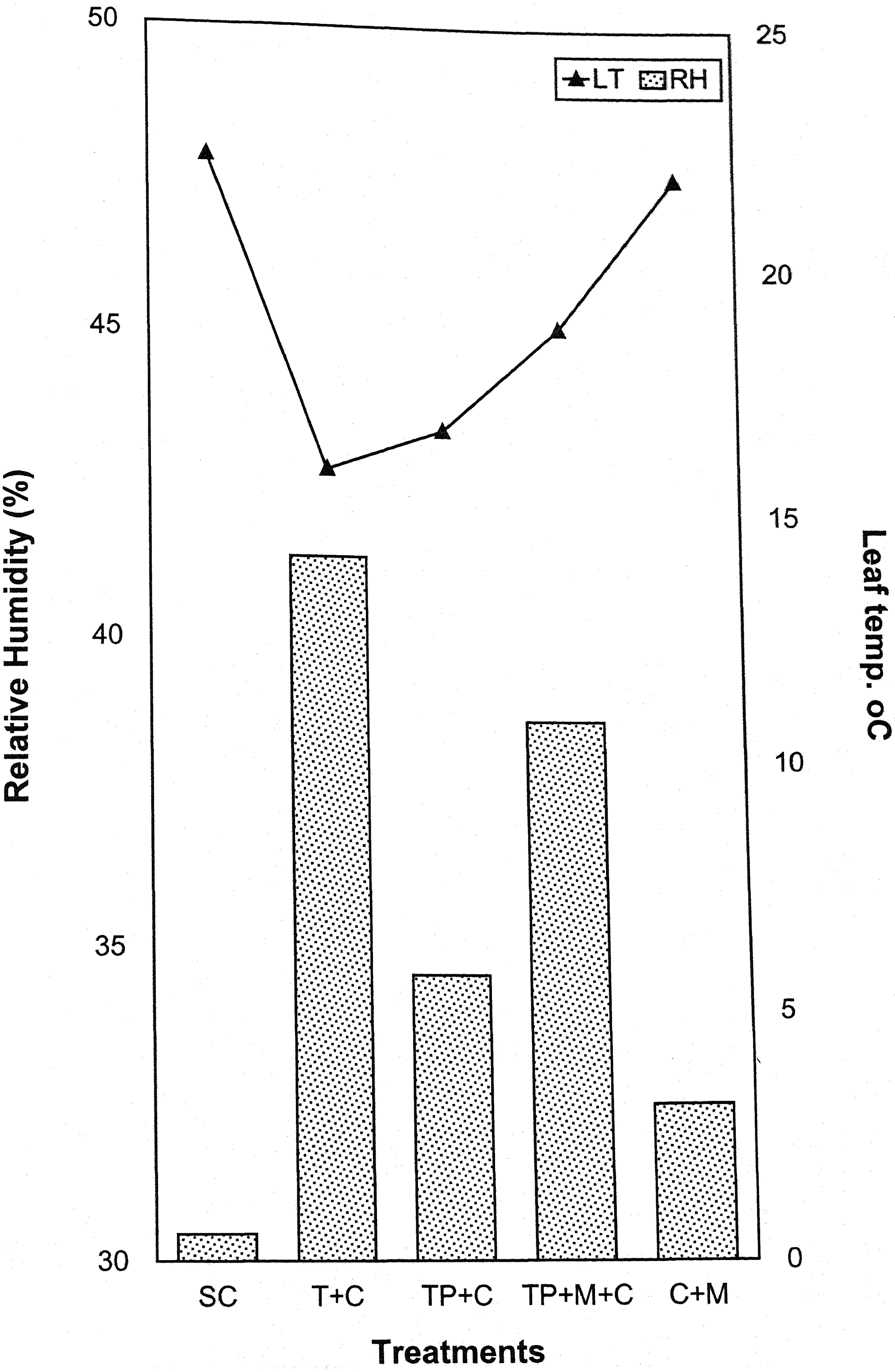


Fig.-6 : Influence of *L. leucocephala* on leaf temperature and relative humidity in *T. aestivum*

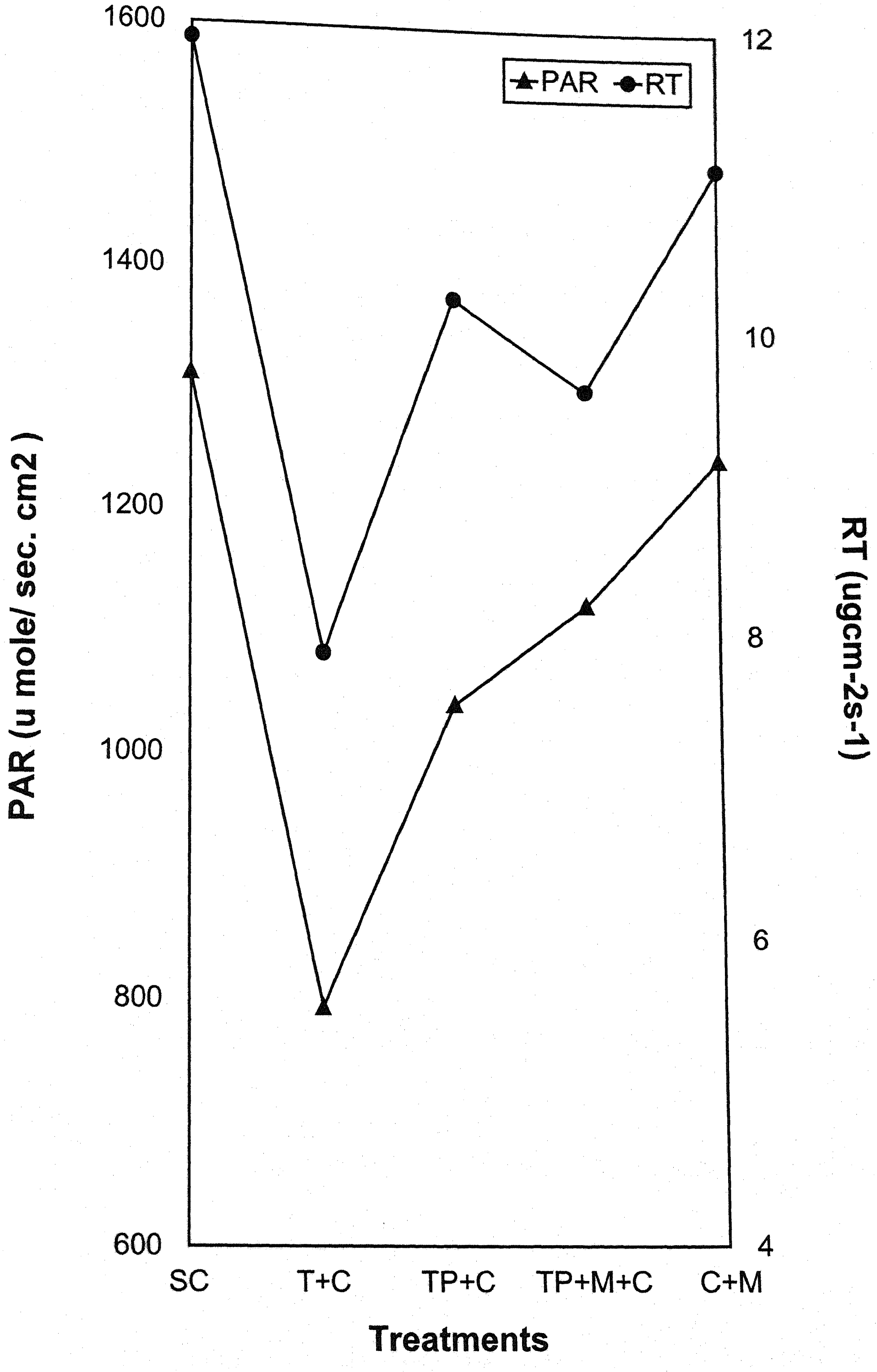


Fig. -7 : Influence of *L. leucocephala* on PAR and rate of transpiration in *T. aestivum*

Physiological parameters of *L. leucocephala*

Physiological parameter viz. leaf temperature, relative humidity, PAR and rate of transpiration of *L. leucocephala* were determined to elucidate the influence of different seasons during May, August, November and February. The results exhibited that the leaf temperature was maximum in May (Fig -8) followed by August and November and minimum in February in sole trees and trees grown in association with intercrop. Leaf temperature was significantly higher in case of tree in association with crop as compared to sole tree.

The relative humidity exhibited an increase in the value for trees grown with crop over sole tree irrespective of seasons. The maximum relative humidity was recorded in August (82 and 78% for tree+crop and sole tree, respectively) followed by November, February and May recorded minimum values for relative humidity (27.2 and 24.8% for tree+crop and sole tree, respectively) as depicted by the fig-9.

The data presented in fig -10 indicated that PAR was maximum in May followed by November and February with its minimum value in August, in sole tree as well as intercrop with tree. However, the data indicated that PAR was maximum (1091and 967μ mole/ sec cm^2) in May followed by November and February with and minimum (835 and 790μ mole/ sec cm^2) in August, in sole tree as well as tree + crop, respectively. However, the value for PAR were significantly higher in case of sole tree irrespective of season then tree + crop (Fig-10).

The rate of transpiration of *L. leucocephala* was maximum in May followed by February, November and August in descending order in tree + intercrop (14.6μgcm^{-2}s^{-1})as well as in sole tree (12.8 μgcm^{-2}s^{-1}).

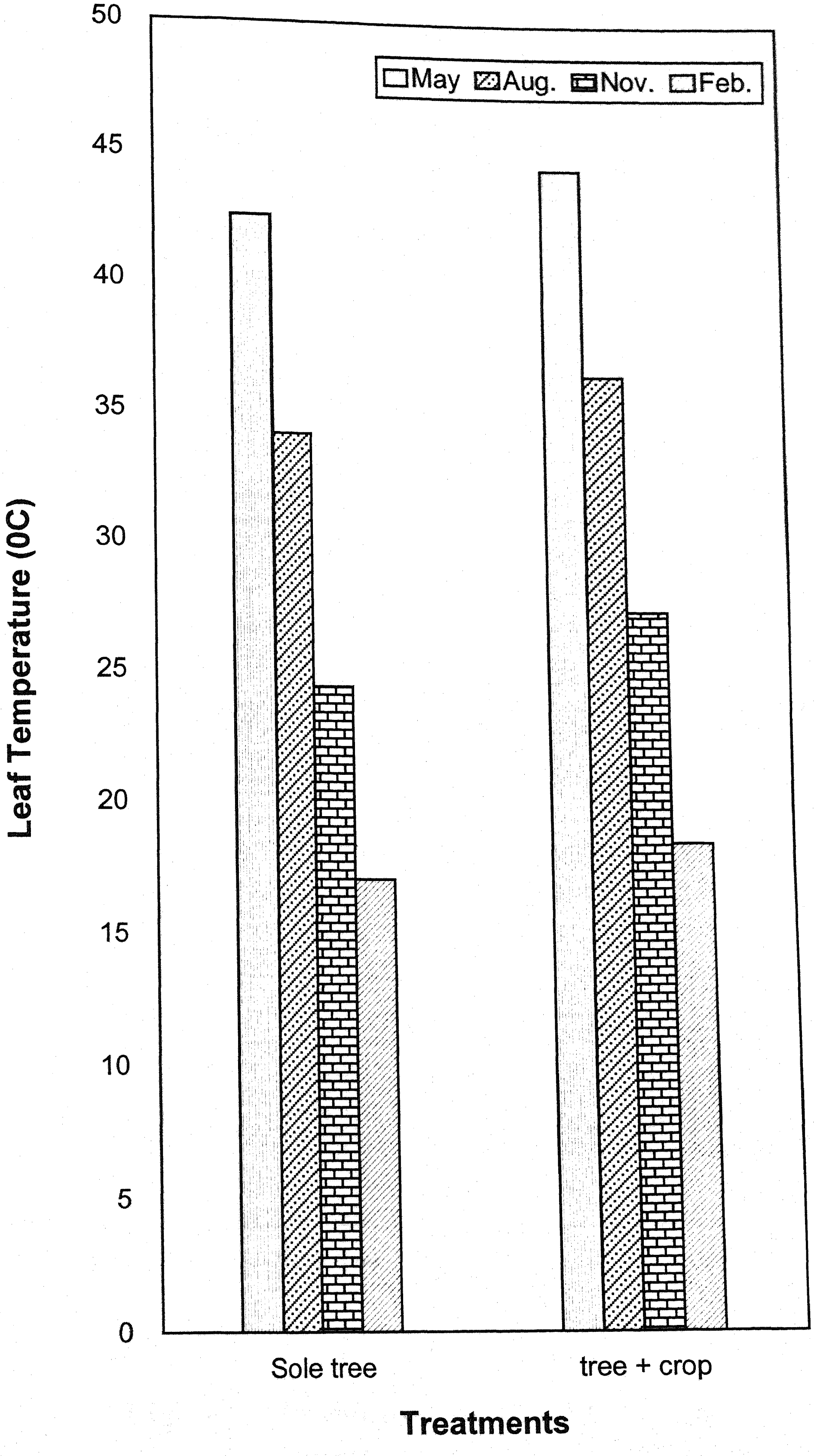


Fig. 8: Influence of seasons on the leaf temperature of *L. leucocephala*

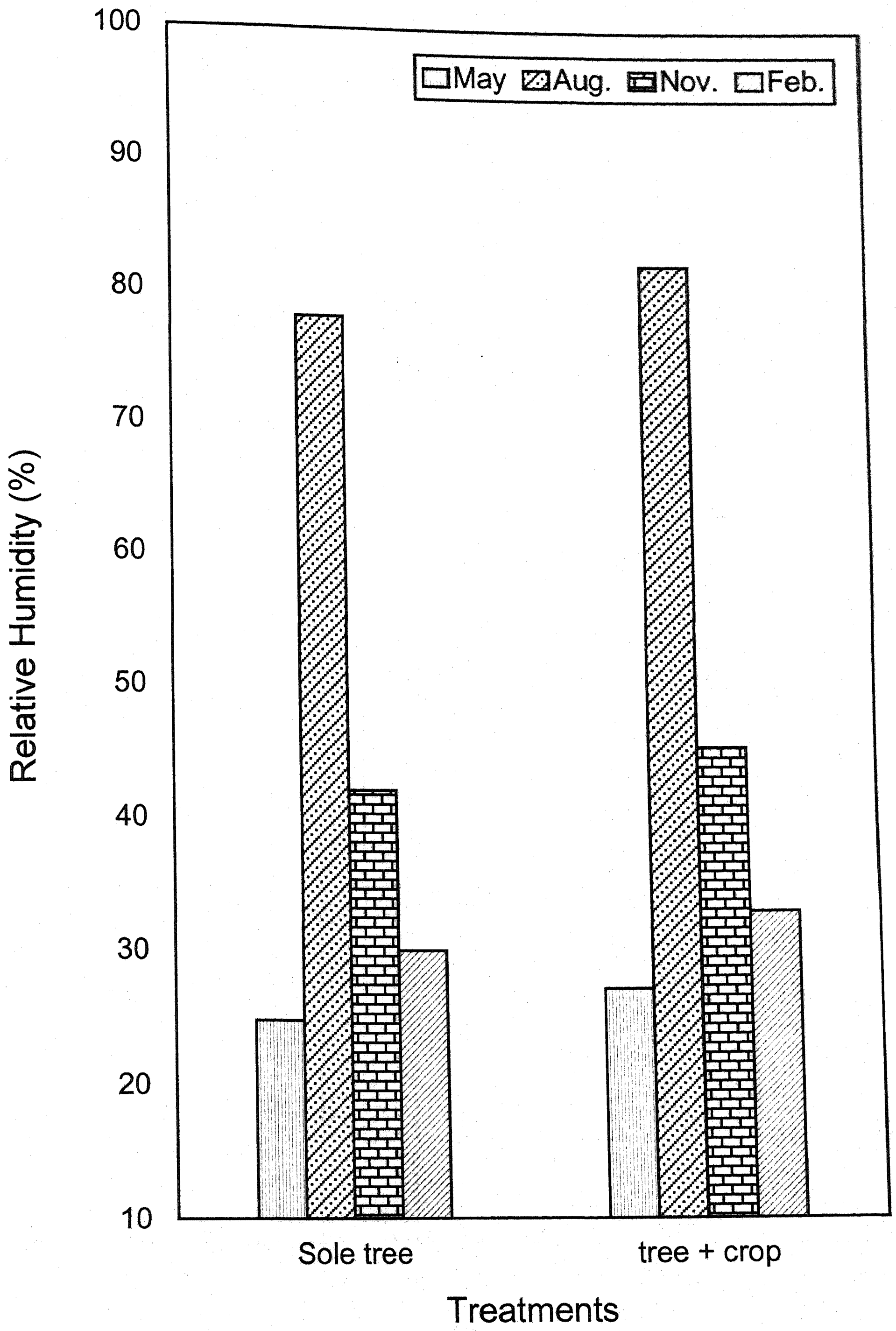


Fig. - 9: Influence of seasons on the relativ humidity of *L. leucocephala*

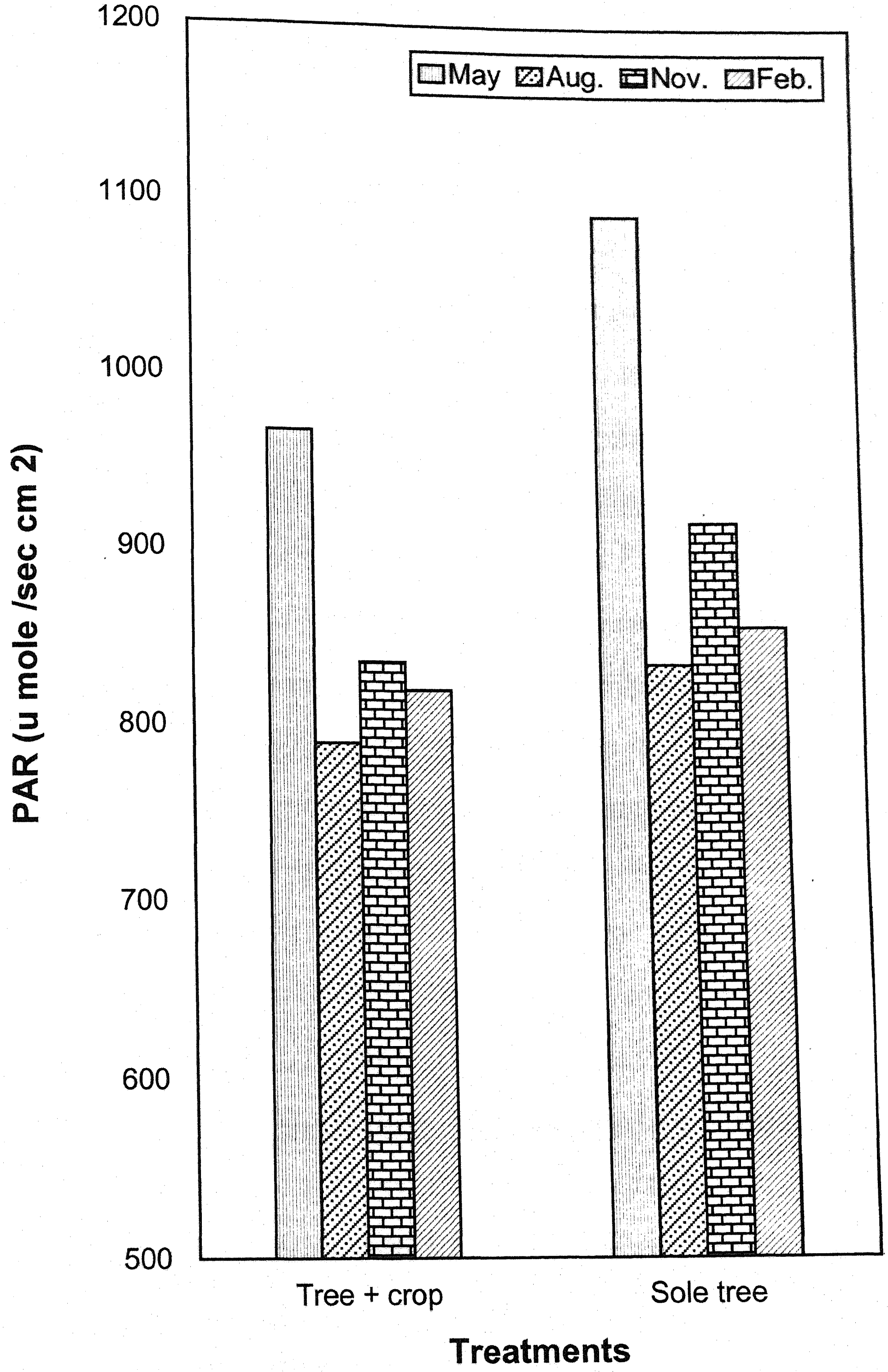


Fig. -10 : Influence of seasons on the PAR of *L. leucocephala*

The rate of transpiration was higher in tree + crop as compared to sole tree while the value were not significantly different during August, November and February (Fig-11).

Growth parameters of *L. leucocephala*

The growth parameters of *L. leucocephala viz.* tree height and collar diameter were studied during 1997-98 and 1998-99. The effect of different seasons on the height of tree shows a well defined trend and on an average tree attained maximum height during May followed by February, November and August in a descending order irrespective of treatments. The spectacular observation from fig. -12 and 13 was that the trees pruned and applied with mulch in association with intercrop attained maximum height (286.75cm and 495.81cm at the end of first and second year, respectively) while the sole tree attained minimum height irrespective of season in *L. leucocephala* (219.18cm and 348.19cm at the end of first and second year, respectively).

Almost similar trend was exhibited by collar diameter of *L. leucocephala* (Fig-14 and 15). The values for sole tree and tree + crop did not show significant difference in all the seasons in *L. leucocephala* in both the years (Fig-14 and 15). The maximum value for collar diameter for *L. leucocephala* were recorded for treatments tree pruned + mulch + crop (2.61cm and 6.05 cm at the end of first and second year, respectively) where as, the minimum values during both the years were recorded for sole tree treatment (2.1 cm and 4.41 cm recorded at the end of first and second year, respectively).

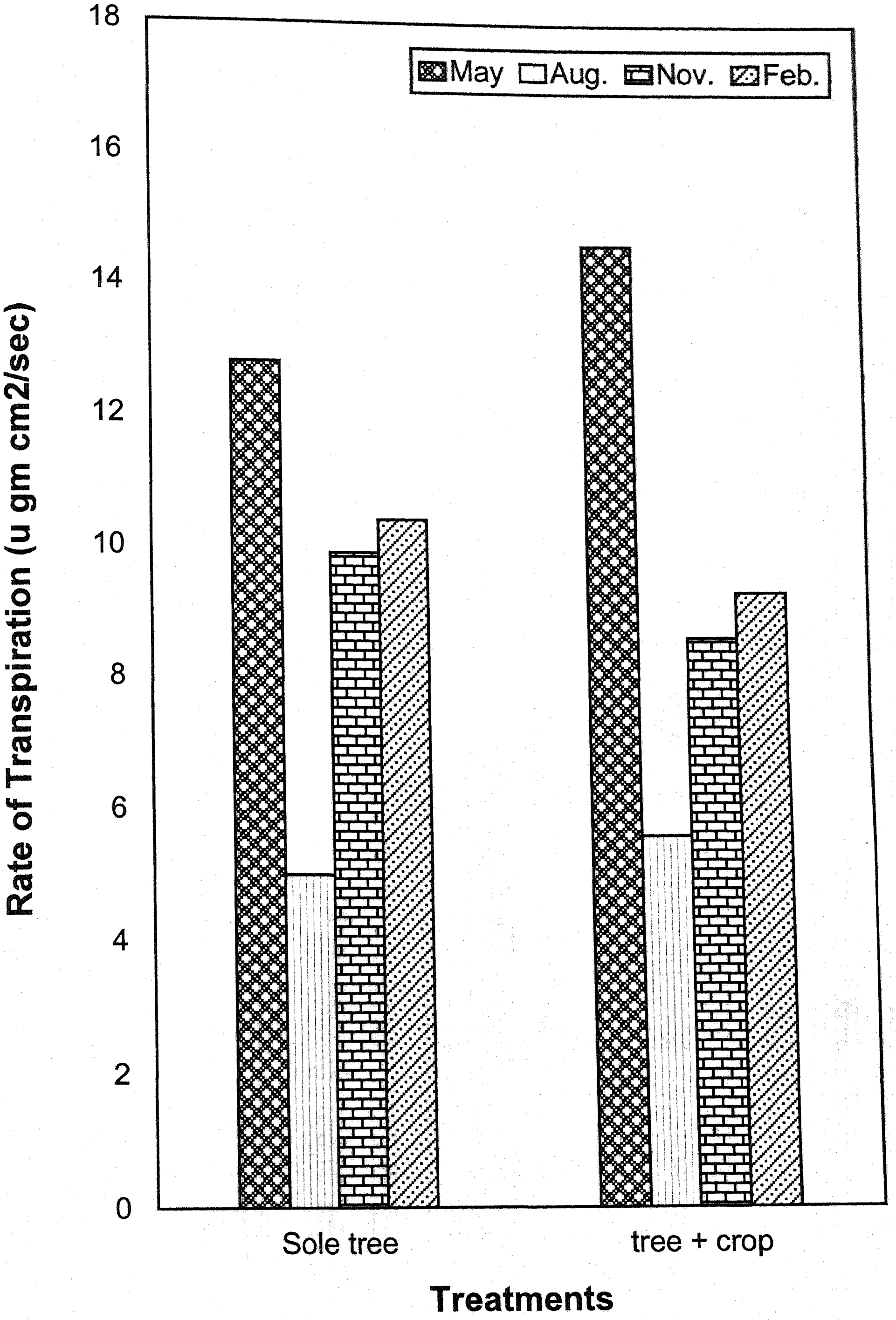


Fig. -11 : Influence of seasons on the rate of transpiration of *L. leucocephala*

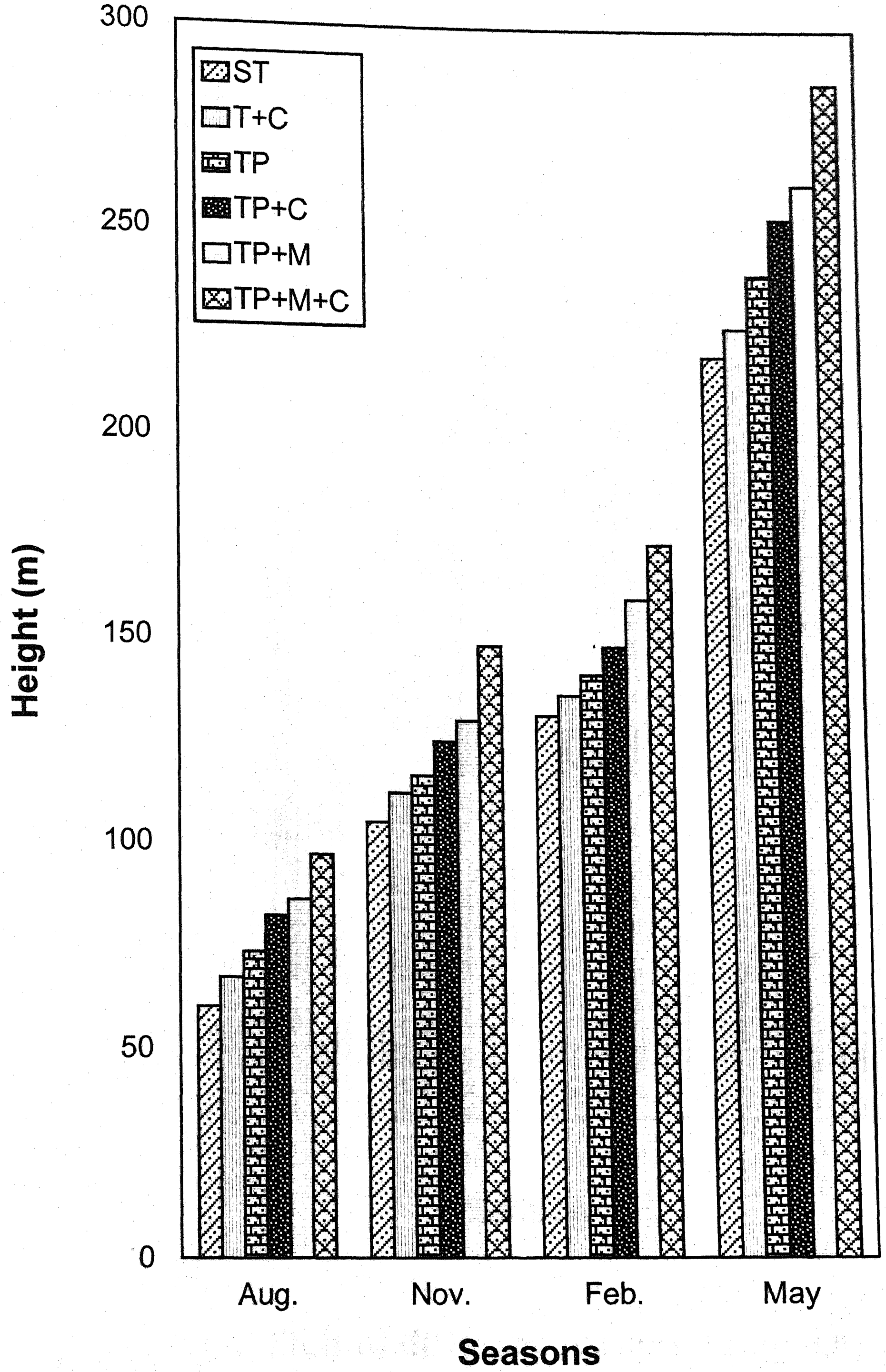


Fig -12: Effect of different seasons on height of *L. leucocephala* during 1997-98

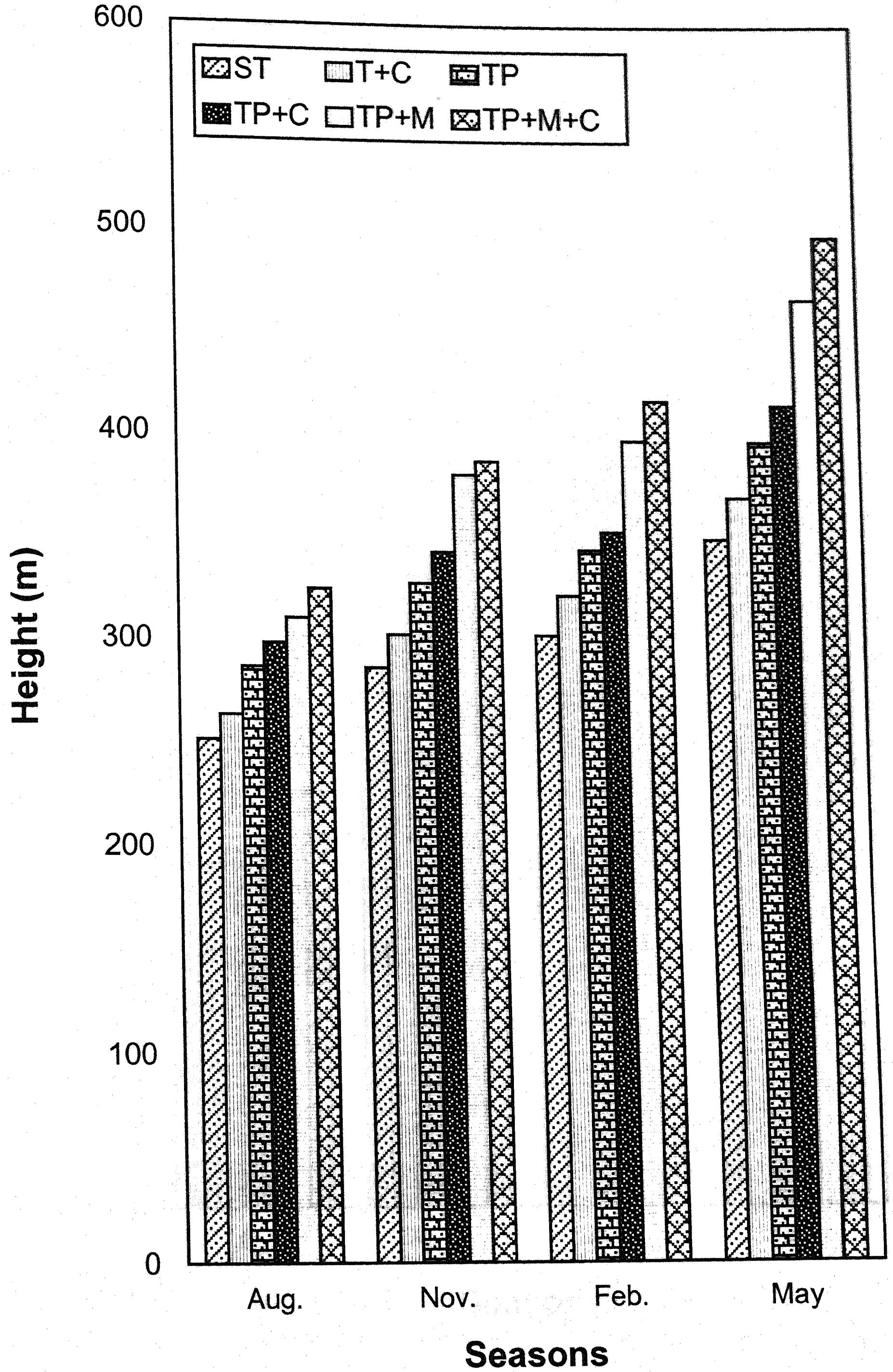


Fig. - 13 : Effect of different seasons on height of *L. leucocephala* during 1998-99

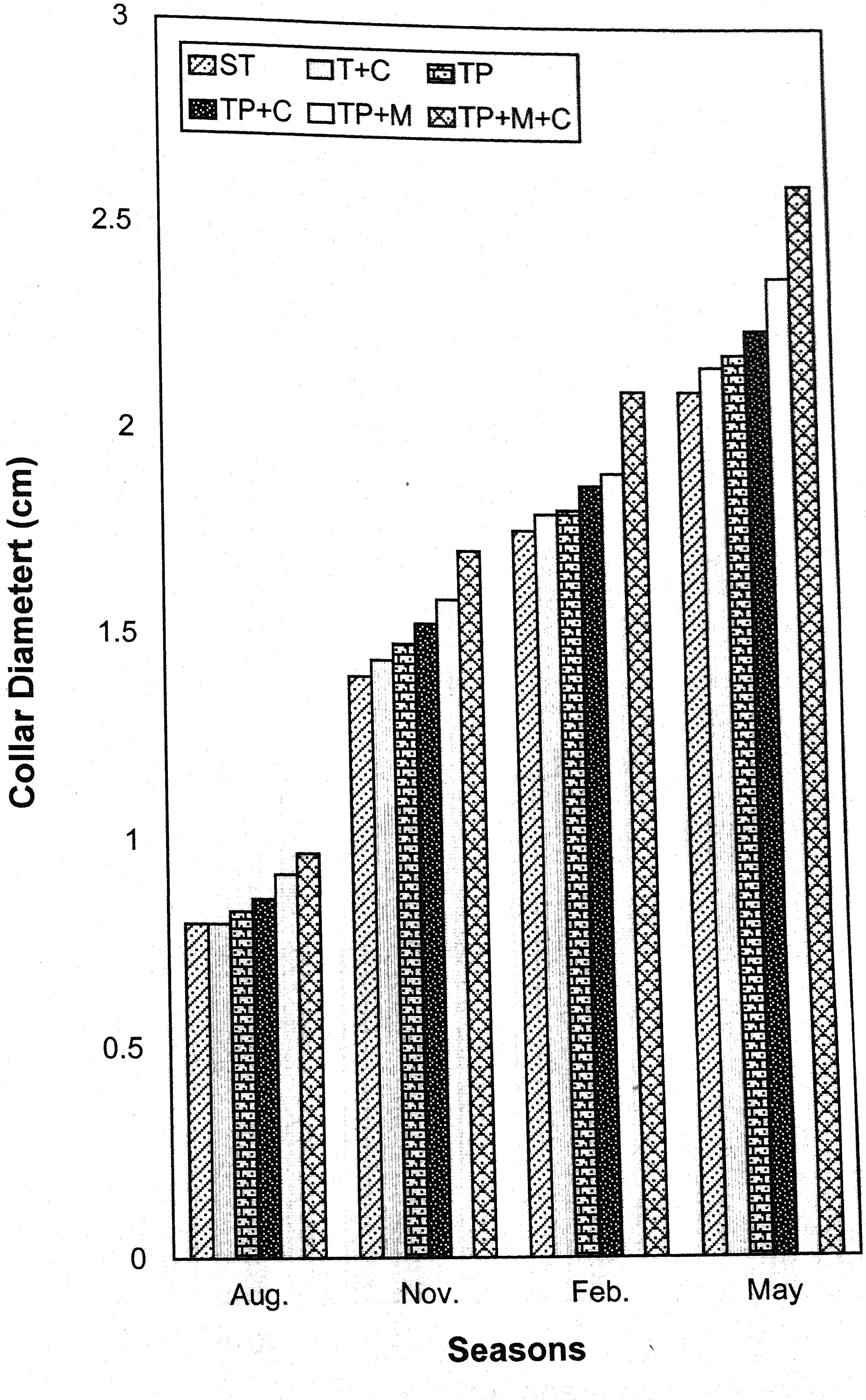


Fig -14 : Effect of different seasons on collar diameter of *L. leucocephala* during 1997-98

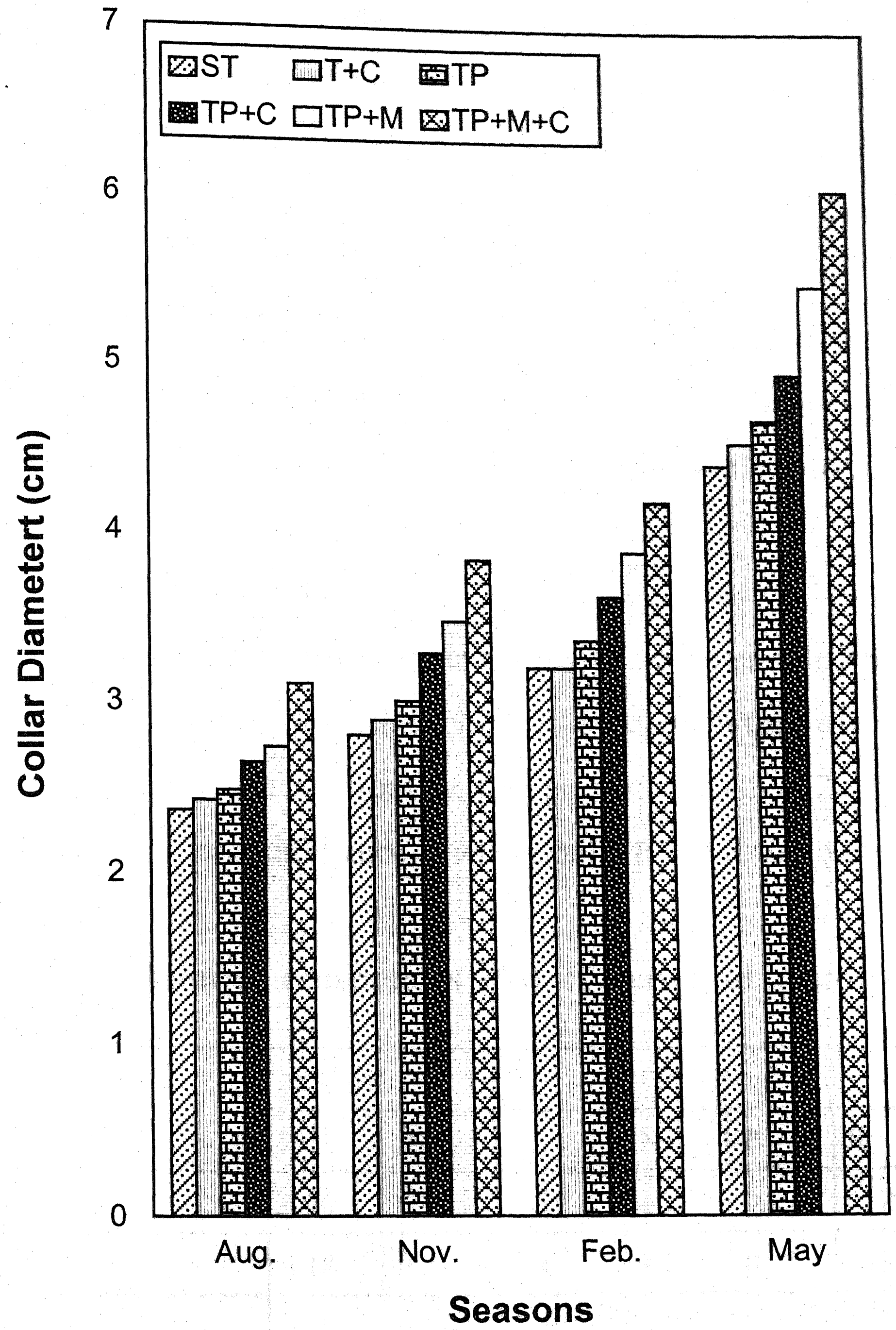


Fig. -15 : Effect of different seasons on collar diameter of *L. leucocephala* during 1998-99

Mimosine concentration

The mimosine concentration was determined in fresh leaves, flowers, pods, decomposed leaves. The results regarding the concentration of mimosine in fresh leaves, flowers, pods and decomposed leaves revealed (Fig. -16) that the average mimosine concentration was 5.53, 6.87, 7.13 and 4.61 per cent, respectively. The maximum concentration was for pods, therefore pod extract exhibited maximum inhibitory effect and the minimum concentration was observed for fresh leaves exhibiting minimum inhibitory effect on both the test crops.

Chemical analysis of leaves

Leaves of *L. leucocephala* were analysed to determine their nitrogen, phosphorus and potassium contents during both the years of experimentation. It is evident from the data presented in table -28 that their was no significant difference in values of N, P and K during two years.

Table 28 : Chemical constituents (%) of leaves of *Leucaena leucocephala*

Treatments	1997-98			1998-99		
	N	P	K	N	P	K
Sole tree	4.26	0.21	1.53	4.28	0.22	1.55
Tree + Pruned	4.18	0.27	1.47	4.21	0.18	1.6
Tree + Crop	4.09	0.18	1.59	4.08	0.3	1.53
Tree Pruned + Crop	4.19	0.24	1.51	4.19	0.27	1.57
Tree + Mulch + Crop	4.31	0.29	1.45	4.35	0.33	1.49
Tree Pruned + Mulch + Crop	4.38	0.33	1.62	4.41	0.35	1.67
Mean	4.23	0.25	1.52	4.25	0.27	1.56

Fig.-16 : Mimosine concentration (%) in different parts of *L. leucocephala*

The maximum nitrogen was estimated in treatments tree pruned supplemented with mulch and crops (4.38%) and the minimum amount of nitrogen was recorded in leaves of trees + crop (4.09%). Similar trend was exhibited in case of phosphorus and potassium (Table-28).There result showed that application of mulch significantly increased the nutrients (N, P and K) in leaves of *L. leucocephala.*

Crude protein and phenol content

The dried leaves of *L. leucocephala* were analysed for the estimation of crude protein and phenol contents. The crude protein content was maximum in treatment tree pruned + mulch + crop during both the years (Table -29). However difference for the crude protein for different treatments during the two years of experimentation was non-significant. The minimum value of crude protein was registered for tree + crop treatment for both the years (20.98 % and 21.03 %, respectively). The total phenol content varies from 17.8 % to 18.4 % for different treatments during both the years with no much difference among various treatments. There was no clear pattern for the total phenol content. The maximum value for total phenol was 18.4 % for tree + crop treatment during 1997-98 and 18.3 % for tree + pruning during 1998-99.However, minimum values were recorded for tree pruned + mulch + crop (17.8 %) and tree pruned + crop (17.7 %) during 1997-98 and 1998-99, respectively. In general, crude protein and total phenol content did not exhibited significant differences for different treatments.

Table 29: Crude protein and phenol content of leaves of *Leucaena leucocephala*

Treatments	1997-98		1998-99	
	Crude Protein (%)	Phenol (%)	Crude Protein (%)	Phenol (%)
Sole tree	21.16	18.3	21.17	18.1
Tree + Pruned	22.07	17.9	22.12	18.3
Tree + Crop	20.98	18.4	21.03	17.9
Tree Pruned + Crop	21.6	18.1	21.63	17.7
Tree + Mulch + Crop	22.3	18.2	22.33	18.1
Tree Pruned + Mulch + Crop	22.9	17.8	22.97	18.2
C.D. (.05)	NS	NS	NS	NS

Changes in soil organic carbon, available Nitrogen, Phosphorus and Potassium: Soil analysis was conducted to determine the effect of different treatments on the organic carbon, nitrogen, phosphorus and Potassium contents of the soil after the termination of the experiment. Data pertaining to changes in soil has been presented in table-30.

Organic Carbon : Soil analysis revealed that the mean value for organic carbon at the termination of the experiment, two years after was 0.54 % indicating an increase of 17.93 % over the initial value of 0.46% recorded at the start of the experiment. Among various treatments tree pruned and applied with mulch showed higher soil carbon contents over other treatments (0.61%), while sole crop had the minimum organic carbon in the soil (0.50%). Application of mulch increased levels of nitrogen and tended to improve the organic carbon content of the soil

and all the treatments incorporating pruning and mulch increased the soil organic carbon content.

Table 30: Changes in soil after termination of the experiment

Treatments	Organic Carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Initial	0.46	214.85	15.19	298.7
Sole tree	0.52	228.35	16.29	312.17
Tree + Pruned	0.53	231.6	17.48	316.05
Tree + Crop	0.51	240.73	16.5	322.1
Tree Pruned + Crop	0.54	246	16.74	329.87
Tree Pruned + Mulch	0.57	253.2	18.27	336.1
Tree Pruned + Mulch + Crop	0.61	260.9	19.83	340.81
Sole crop	0.5	225.11	16	319.64
Crop + Mulch	0.56	247.12	17.1	330.84
Mean	0.54	241.62	17.27	325.94

Available Nitrogen : Available nitrogen content in the soil after the termination of the experiment followed the similar trend observed for the organic carbon content. On an average, two years of experimentation increased the available soil nitrogen to 241.62 kg/ha over the initial value of 214.85 kg/ha, registering in an increase of 12.46% over initial value. The increase in available nitrogen was maximum in the tree pruned supplemented with mulch (260.90). Application of mulch and pruning improved the available N in the soil after two years of experimentation over the initial available N content

(214.85kg/ha). The least increase in available nitrogen content was observed for treatment sole crop, which recorded 225.11kg/ha N after two years. There was an increment in N level in soil as compared to the initial available nitrogen.

Available Phosphorus : The trend for available phosphorus content in the soil after the termination of the experiment was in the similar way as observed for the nitrogen content. On an average, two years of experimentation increased the available soil phosphorus by 13.73 % to 17.27 kg/ha over the initial value of 15.19 kg/ha, recorded at the time of initiation of the experiment. Thus exhibiting an increase of 2.08 kg/ha over initial value. The increase in available phosphorus was maximum in the treatment tree pruned plus application of mulch. Application of mulch improved the available P in the soil after two years of experimentation over the initial available P content (4.64 kg/ha). There was an increment in P level in soil as compared to the initial available phosphorus.

Available Potassium : Available potassium content in the soil after the termination of the experiment followed the similar trend as observed for the available phosphorus content. Two years of experimentation, on an average increased the available soil potassium by 27.24 kg/ha over the initial value of 298.70 kg/ha exhibiting an increase of 9.12 % during the period of experimentation. The increase in available potassium was maximum in the tree pruned supplemented with mulch. There was an increment in K level in soil as compared to the initial available phosphorus.

DISCUSSION

DISCUSSION

Allelopathy has currently been gaining spectacular acceptance in India as a factor having ecological significance in plant dominance, patterning of vegetation, succession, crop productivity and agroforestry system and a number of species with allelopathic potentials have been identified (Parihar, 1985; 1994; Melkania, 1992; 1994; Narwal, 1996; Tripathi *et al.*, 1998; Paneerselvam *et al.*, 1998; Dharamraj, 1998; Bisla *et al.*, 1998).

Considerable research work on allelopathy has been done in developed countries and has been implicated in major problems related to crop production, agriculture, horticulture and forestry. Allelopathic studies has also been initiated in India and some significant information has been generated (Narwal,1994). Numerous allelochemicals are released from plant primarily through leaching from above-ground parts and affects the chemical properties of soil. It has been ascertained that dominant plant species exert influence on the floor conditions and nutrient availability. However, now, it is evident that allelopathy plays a decisive role in the development of species and community structure under the canopy of that particular species (Inderjit and Dakshini, 1991; Malik and Surendaran, 1998; Palani and Dasthagir, 1998).

The present experimental findings are discussed in light of the observations keeping in view the stimulatory or inhibitory effect of *Leucaena leucocephala* or other tree species on crops of other researchers and in cases where there were no reports on the influence of *Leucaena leucocephala* or other tree species on *Triticum aestivum* and *Glycine max*. The results obtained through present studies are discussed

on the succeeding pages under following three headings :

1. Allelopathic influence under laboratory conditions,

2. Allelopathic influence under nursery conditions and

3. Allelopathic influence under field conditions

1.Allelopathic influence under laboratory conditions

The allelopathic studies on influence of *Leucaena leucocephala* on *Triticum aestivum* and *Glycine max* under laboratory conditions incorporates the influence of aqueous extract of fresh leaves, flowers, pods and decomposed leaves. Exogenous pretreatment of aqueous extract of *Leucaena leucocephala* leaves significantly accelerated seed germination up to a concentration of 40% and inhibited at 80 and 100% as compared to control both in *Glycine max* and *Triticum aestivum* (Fig.-1 and 2, respectively). The results exhibited the maximum stimulatory effect on seed germination at 40 % concentration and it was inhibited to the maximum extent at 100 % which was closely followed by 80 % concentration. The present findings that aqueous extract of leaf, flower and pod of *Leucaena leucocephala* stimulated the seed germination and growth in *Triticum aestivum* (Plates -1 to 4) in *Glycine max* (seed germination Plates- 5 to 7; seedling growth Plates- 8 to 10) at lower concentration are in agreement with those reported earlier for *Vigna mungo* and *Glycine max* (Dharamraj,1998), *Oryza sativa* (Chou, 1983; Chaturvedi and Jha,1992), *Cajanas cajan, Sesamum indicum, Raphanus communis* and *Sorghum bicolor* (Singh,1983). The stimulatory effect was also observed at lower concentration due to the aqueous extract of *Populus deltoides* in *Triticum aestivum, Lens esculanta, Cicer aretinum* (Carley and Watson,1967; Bisla *et al.*,1992).

The inhibitory effect observed on seed germination at higher concentrations is in accordance with similar effect of *Leucaena leucocephala* on different species *viz. Triticum aestivum* and *Zea mays* (Chaturvedi and Jha,1994), *Triticum aestivum* and *Oryza sativa (*Rao *et al.*, 1995), *Glycine max* and *Vigna mungo* (Dharamraj,1998). *Oryza sativa* (Chaturvedi and Jha,1992), *Lactuca sativa* and *Oryza sativa*(Wilson and Bell, 1979; Chou and Kuo, 1986; Koul *et al.*, 1983) *Acacia confusa, Casuarina clauca* and *Alnus formosana* (Chou and Kuo, 1986*), Oryza sativa, Raphanus sativus, Brassica rapa, Phaseolus vulgaris, Daucus carota* and *Bidens pilosa* (Tawata and Hongo,1987), *Sorghum bicolor, Vicia faba* and *Helianthus annus.*(Swaminathan *et al.*, 1989), *Oryza sativa* (Koul *et al.*, 1991), *Lactuca sativa* and *Lolium perenne* (Chou,1989) .

In addition to the aforesaid observations, aqueous extract of leaves of *Eucalyptus tereticornis* reduced seed germination in *Triticum aestivum* and *Brassica compestris* (Puri and Khara,1991; Puri, 1992), *Triticum aestivum, Zea mays, Pisum sativum, Brassica compestris*, and *Lens esculanta* at higher concentrations (Joshi and Prakash,1992). The results obtained are duly supported by the finding that the aqueous extract of *Populus deltoides* in *Triticum aestivum* and *Cicer aretinum* (Melkania,1984), *Prosopis glandulosa* in *Triticum aestivum* (Alam and Azmi, 1989; Azmi and Alam, 1989) and *Triticum aestivum* and *Zea mays* (Nimbal *et al.*, 1990) inhibited seed germination at higher concentration. Similar results have also been reported for aqueous extract of *Acacia nilotica* in *Brassica compestris, Lens esculanta, Pisum sativum* and *Triticum aestivum* (Bhatt and Todaria,1992), in *Acacia nilotica* and *Acacia tortilis* in *Triticum aestivum, Cicer aretinum*

and *Brassica compestris* (Saxena *et al.*, 1995). The aqueous extract of *Casuarina equisetifolia* in *Vigna radiata, Vigna mungo, Vicia faba, Cajanus cajan* and *Glycine max* (Srinivasan *et al.*, 1990), *Acacia nilotica* on *Triticum aestivum* (Solanki *et al.*, 1999), exhibited inhibitory effect on seed germination.

The aqueous extract of fresh leaves, flowers and pods affected growth parameters such as shoot, root, seedling elongation, fresh and dry weight of shoot, root and seedling and moisture content of both the crops in the same manner as seed germination was influenced. Therefore, the aqueous extract stimulated the growth at 20 - 40% and inhibited at 80 and 100% in *Triticum aestivum* (Tables -1 to 6) and *Glycine max* (Tables -9 to 14). In agreement with these results, the growth reduced in seedling of *Sorghum bicolor, Vicia faba* and *Cymopsis tetragonoloba* (Deshwal and Nandal,1996) due to the effect of *Leucocephala leucocephala* extract, whereas, Chouhan *et al.*, (1992), reported the non-significant effect of *Leucaena leucocephala* on the growth of grass. The inhibitory effect of aqueous extract of *Prosopis glandulosa* on growth and productivity of *Triticum aestivum* (Alam and Azmi, 1989; Azmi and Alam, 1989), *Acacia nilotica* on *Brassica compestris, Lens esculanta, Pisum sativum* and *Triticum aestivum* (Bhatt and Todaria,1992; Dalal *et al.*, 1992), *Acacia nilotica* and *Acacia tortilis* on *Triticum aestivum, Cicer aretinum* and *Brassica compestris* (Saxena *et al.*, 1995), on *Triticum aestivum, Brassica compestris* and *Cicer aretinum* (Solanki *et al.*,1999), confirmed the findings of these studies. Extract of *Casuarina equisetifolia* inhibited seedling growth and its productivity in *Vigna radiata, Vigna mungo, Vicia faba, Cajanus cajan* and *Glycine max* (Srinivasan *et al.*, 1990). Contrary to above reports, the aqueous extract

of *Acacia nilotica* stimulated the seedling length of *Glycine max*.(Tripathi *et al.,* 1998). The aqueous extract of *Tectona grandis* promote the growth of *Glycine max* (Tripathi and Tripathi, 1997). In addition to the aforesaid findings, Smith and Fowden, (1996), reported that Leucaena's own seedling growth remained unaffected due to the aqueous extract of *Leucaena leucocephala*.

The influence of aqueous extract of decomposed leaves on germination, growth and productivity of both the crops was found similar to that obtained for aqueous extract of fresh leaves, flowers and pods, and stimulated the germination and growth at 20 - 40% and inhibited at 80 and 100%.(Tables -7 & 8 for *Triticum aestivum* and Tables -15 & 16 for *Glycine max*). However, the stimulatory effect was less as compared to fresh leaves but was more as compared to flower and pod extract. Similarly, inhibition was more than fresh leave extract but less than flower and pod extract. It may be attributed to the fact that the mimosine content was more in pod and flower as compared to decomposed leaves perhaps due to bio degradation of mimosine.

The results regarding the concentration of mimosine in fresh leaves, flowers, pods and decomposed leaves revealed that the mimosine concentration was 5.53, 6.87, 7.13 and 4.61 per cent, respectively. These findings further strengthen the results of the studies about the influence of *Leucaena leucocephala* on both the crops that the maximum inhibition was observed for pod extract and minimum for decomposed leaves. It also confirmed that inhibition was maximum at higher concentrations compared to lower concentrations of extract due to less concentration of mimosine. Earlier it has been reported that the concentration of mimosine was maximum in pods and minimum in

decomposed leaves of *Leucaena leucocephala*. Jones (1981), also reported that mimosine concentration was less in decomposed leaves compared to fresh leaves.

The stimulation in seed germination of *Triticum aestivum* and *Glycine max* may be attributed to some phenolic compounds like, non-proteineous amino acid mimosine, gallic acid, vanillic acid, ferulic acid, p-coumaric acid etc. present in the aqueous extracts of *Leucaena leucocephala*, which promote the germination of seeds at lower concentrations and inhibit at higher concentrations ultimately inhibiting the seed germination and seedling growth. Therefore, the studies conducted in laboratory revealed that seed germination and seedling growth of *Triticum aestivum* and *Glycine max* could be enhanced with the pretreatment of the aqueous extract of fresh leaf, flower, pod and decomposed leaves of *Leucaena leucocephala* up to 40 % concentration. The maximum inhibitory effect among the various parts of *Leucaena leucocephala* was observed for pod extract, it may be attributed to the fact that mimosine content was maximum in pod and stimulatory effect was maximum due to fresh leaf extract which appears to contain minimum amount of mimosine. This further strengthens our conclusion that mimosine is the substance in aqueous extract of *Leucaena leucocephala* responsible for the stimulatory and inhibitory effect of *Leucaena leucocephala* depending on its concentration. These findings are in line with those of Tawata and Hongo (1987), who also reported that mimosine promoted the growth of *Oryza sativa, Raphanus sativa* and *Brassica rapa* at lower concentrations whereas, inhibited the growth at higher concentrations. Moreover mimosine appeared to be selective for certain plant strains and the influence varied for different plant

species. This is further confirmed by the findings of Inderjit (1996), that concentration of allelopathicaly active phenols vary for species to species and stages of growth and development of the test crops.

Allelopathic influence under nursery conditions

The results obtained through laboratory studies were further confirmed through the studies conducted under nursery conditions. These studies were carried by using soil collected beneath the *Leucaena leucocephala* plantations mixed with the field soil with varying ratio to confirm the allelopathic influence of the species. These studies were conducted to minimise the biasness, if any due to higher concentrations of laboratory studies, which otherwise were not prevalent under nursery conditions.

These studies exhibited that soil beneath *Leucaena leucocephala* played a significant role in stimulating the germination, growth and productivity of *Triticum aestivum* and *Glycine max*. The stimulatory effect was maximum for one part of *Leucaena leucocephala* soil and three parts of field soil, whereas, all the parameters exhibited maximum inhibitory effect with hundred percent soil beneath the *Leucaena leucocephala* plantations for both the crops *Triticum aestivum* (Table - 17 & 18 and Plate- 11) and *Glycine max* (Table- 19 & 20 and Plate -12 & 13).

The present experimental findings may be attributed to the fact that soil beneath *Leucaena leucocephala* contains mimosine , accumulated due to leaching from the leaves. Further, *Leucaena leucocephala* being a nitrogen fixing tree adds nitrogen to the soil beneath its plantation, but as the hundred percent soil beneath the *Leucaena leucocephala* plantations resulted in inhibitory effect. It

appears that concentration of mimosine was much higher in this soil which overcomes the stimulatory effect due to the presence of nitrogen. These results are confirmatory with the findings of Chaturvedi and Jha (1994), who reported the influence of *Leucaena leucocephala* on *Triticum aestivum* and *Zea mays* and Dharamraj (1998), in *Vigna mungo* and *Glycine max* that at higher concentration of mimosine inhibited the seed germination, growth and its productivity but enhanced significantly at lower concentrations.

The influence of soil beneath the *Leucaena leucocephala* on growth of these test crops in line with the findings of Smith and Fowden (1966), who reported a conceptual model to understand the allelopathic mechanism in the soil rhizosphere. Further, he suggested that retention, transformation, and transport of chemicals in soil and physico - chemical and biological components of soil influence the fate of allelopathic chemicals, thus allelopathy in soil.

The soil beneath *Leucaena leucocephala* plantations influenced both crops in same trend but the magnitude of influence for both the crops was different. The stimulatory and inhibitory effects were more pronounced in *Triticum aestivum* as compared to *Glycine max*. This may be attributed to the fact that different species responded differently to the influence of mimosine and other growth regulatory factors, as many workers reported different spectrum of effect for other crops. Korwar and Radder (1991), reported inhibitory effect of *Leucaena leucocephala* on the *Sorghum bicolor*. Contrary to the above observation, Pathak (1988), reported stimulatory effect of *Leucaena leucocephala* on growth and yield of *Zea mays*. The inhibition of growth at 100 per cent *Leucaena leucocephala* soil was in line with the findings of Dakshini

and Inderjit (1996), who reported changes in soil chemistry not only in building toxic chemical pool but also through the effect of its organic molecules on soil organic ions and microorganisms and also suppress the root growth of cereals, when the field soil was mixed with debris of *Pluchea lanceolata.*

Allelopathic influence under field conditions

The field studies on allelopathic potential of *Leucaena leucocephala* on *Triticum aestivum* and *Glycine max* were conducted to confirm the results obtained through laboratory and nursery conditions. The studies were conducted in the experimental farm area of NRCAF, Jhansi (Plate - 20). The data were recorded for both the intercrops for plant population, growth and yield parameters pertaining to the stimulatory or inhibitory influence of *Leucaena leucocephala* were compared over control treatment (intercrops grown without trees of *Leucaena leucocephala).* The results obtained from the experiment have been discussed in the succeeding pages in light of the available literature.

Growth parameters of *Leucaena leucocephala*

The data for growth parameters of *Leucaena leucocephala* namely tree height and collar diameter were recorded during 1997-98 and 1998-99. The effect of different seasons on the height of tree exhibited a well defined trend and on an average tree attained maximum height during Feb- May followed by August-November. This showed that the spring season is the best season for the growth of this species (Fig. -12 & 13). The spectacular observation was that the trees pruned and applied with mulch in association with intercrop attained maximum height while the sole tree attained minimum height irrespective of season

in *Leucaena leucocephala* in both the years. The earlier reports of Bisaria et al.,(1999), also confirmed this trend of tree growth with and without cop. They reported that mean annual increment for height and diameter of *Tectona grandis* and *Azadirachta indica* was more in association with crop compared to sole tree. This may be assigned to factor that there is some complimentary interaction between tree and crop for tree growth parameters when grown in association.

Almost same pattern was exhibited by collar diameter of *Leucaena leucocephala*. The values for sole tree and tree + crop did not show significant difference during all the seasons in *Leucaena leucocephala* in both the years. The maximum value for collar diameter for *Leucaena leucocephala* were recorded for treatments Tree pruned + mulch + crop during both the years where as, the minimum values during both the years were recorded for sole tree treatment (Fig.-14 & 15).

The results for tree height and collar diameter revealed that maximum values were recorded in association with crop may be attributed to the fact that the trees growing in association of crop were benefitted due to the presence of crop. The pruning also influenced the tree growth parameters positively. Thus, the trees of *Leucaena leucocephala* may be managed for maximum productivity through pruning and by utilizing the interspace for growing crops in agroforestry system. The reduction in crop yield due to the presence of trees can be managed by proper pruning and application of mulching. The reduction in yield under these treatments over the control can be compensated through fodder, fuelwood from the trees received as end product of pruning and enrichment of soil due to litter and biological nitrogen fixation.

Growth parameters of intercrops

Allelopathic influence of *Leucaena leucocephala* was determined on *Glycine max* and *Triticum aestivum*. The perusal of data revealed that plant population per m row and plant height of *Glycine max* were higher under sole crop over tree + crop treatment. The plant population per m row was affected due to management practices (Table - 21) and it was minimum under unpruned tree with crop (Plate - 14) compared to tree pruned + crop and tree pruned + mulch + crop. This trend was found same for both the years but reduction was more profound during second year which may be attributed to the increased influence of *Leucaena leucocephala* trees on intercrop due to increased size of tree and allelopathy. Therefore, during both the years the plant population per meter row and the plant height of *Glycine max* and *Triticum aestivum* was significantly reduced by *Leucaena leucocephala*. The height of plant was significantly higher over tree + crop, crop in association with Leucaena's tree pruned and crop. The maximum plant height was recorded in crop applied with mulch (Table -21). The number of branches per plant was maximum in the treatment, crop + mulch (11.0/plant) followed by sole crop (Table -22) and minimum number of branches per plant were recorded in tree + crop (6.00/plant). Number of *leaves /plant for* Glycine max *exhibited the similar response to that of* branches per plant and in the crop + mulch number of leaves were maximum (78.22/plant) followed by sole crop (64.10) and was minimum for tree + crop treatment (42.27). The trend was same for second year but reduction was more pronounced than first year (Table -22). It may be attributed to the fact that tree growth was more in second year compared

to first year and the magnitude of influence due to *Leucaena leucocephala* increased in second year. A significant reduction in number of leaves per plant was observed in the treatment tree + crop, tree + pruned + crop, tree + pruned + mulch + crop respectively over sole crop. Quantitative flowering was significantly inhibited in association with *Leucaena leucocephala.*

The same set of experiment was conducted in field for *Triticum aestivum* during rabi season for both the years. The trend for plant population, growth parameters and yield parameters were similar to that observed for *Glycine max.* The plant population per m row and plant height of *Triticum aestivum* was minimum when crop was grown in association with *Leucaena leucocephala* as compared to sole crop (Plate -15). The reduction over control was also recorded for tree pruned + crop (Plate -16), tree pruned + mulch + crop (Plate -17) over sole crop but the reduction was less when compared with tree + crop (Table -25 and Plate -18). The plant height followed the same trend for different treatments as observed for plant population (Table -25). This may be attributed to the fact the pruning and mulch practices enhanced the productivity of intercrop by improving the microclimate.

The results obtained through this experiment concluded that there was a stimulatory effect of *Leucaena leucocephala* trees on these crops when some management practices like pruning and mulching were applied but when these practices were not used the growth parameters of both the crops were affected due to the presence of *Leucaena leucocephala* plants.

Physiological Parameters

Intercrops

The results obtained from the studies conducted revealed that the physiological parameters of intercrop were affected due to the canopy of *Leucaena leucocephala*. These effects were more pronounced when the parameters in tree + crop treatment were compared with management treatments such as pruning and mulch. The leaf temperature, rate of transpiration and PAR of inetrcrops reduced significantly under *Leucaena leucocephala* canopy, whereas, relative humidity enhanced significantly due to canopy. These findings are in line with those reported earlier by Bisaria *et al.*,(1999), for the physiological parameters of inetrcrops (blackgram and mustard) under the canopy of *Hardwickia binata*. The reduction in leaf temperature of *Glycine max* (Fig.- 4), rate of transpiration (Fig.- 5) and PAR (Fig.-5), in association with trees may be due to the fact that tree canopy provided a cover to the understorey crop and thus modified the microclimate for the intercrops. The same trend was observed in *Triticum aestivum* for leaf temperature(Fig. -6), rate of transpiration (Fig.- 7), and PAR (Fig.-7). Earlier also Bisaria et al (1998), reported the same trend for these physiological parameters of the intercrops due to changes in microclimate under agroforestry systems compared to sole crop. The trend for these parameters was same for both the crops. It can be further confirmed by the findings that the leaf temperature of *Crysopogan fulvus* was less under tree canopy (*Acacia nilotica, Dalbergia sissoo* and *Hardwickia binata)* compared to open conditions and leaf temperature further reduced when tree canopy was pruned (Bisaria *et al.*, 1999). These observations for the

parameters were in line for the observations recorded for the growth and yield parameters of the intercrops and were clearly exhibited for the growth and yield parameters of the intercrops.

Leucaena leucocephala

Physiological parameter viz. leaf temperature, relative humidity, PAR and rate of transpiration of *Leucaena leucocephala* leaves were determined to elucidate the influence of different seasons during May, August, November and February. The results exhibited that the leaf temperature was maximum in May followed by August and November and minimum in February (Fig. -8), in sole trees and trees grown in association with intercrop. Leaf temperature was significantly higher in case of tree in association with crop as compared to sole tree. The results obtained in this experiment were in line with the earlier findings of Bisaria *et al.,* (1998; 1999), who reported the maximum leaf temperature of *Hardwickia binata* in May followed by August and November and minimum in February and the leaf temperature was significantly higher in case of tree in association with crop as compared to sole tree. The results are in line with the findings of Shanker *et al.* (2000), who also reported the similar changes in microclimate due to agroforestry systems.

The relative humidity exhibited a promoted trend in trees grown with crop over sole tree irrespective of seasons. The maximum relative humidity (Fig.-9), was recorded in August followed by November, February and May which exhibited a descending order.

The PAR was maximum in May followed by November and February with its minimum value in August, in sole tree as well as

intercrop with tree (Fig.10). However, the value for PAR were significantly higher in case of sole tree irrespective of season in *Leucaena leucocephala*. This may be credited to factor that maximum sunlight was available during May thus resulting in maximum value of PAR and during August minimum value was recorded due mainly cloudy sky during that period resulting in minimum sunlight available for the system. This findings confirmed the earlier reports of Bisaria et al (1998; 1999), who also reported the same trend for these physiological parameters of *Hardwickia binata*. Seema *et al.* (2000), reported the similar trend for physiological parameters of *Leucaena leucocephala* thus further strengthening the present findings.

The rate of transpiration of *Leucaena leucocephala* was maximum in May followed by February, November and August in descending order in sole tree as well as in tree + intercrop. The rate of transpiration was higher in tree + crop as compared (Fig. -11) to sole tree while the value were not significantly different during August, November and February.

Yield parameters of intercrops

The studies conducted in the field revealed that the minimum number of flowers (32.65/ plant) were recorded in *Glycine max* in association with tree (Table -23). The reduction in quantitative flowering was further checked by adding mulch and therefore, the maximum number of flowers (52.75) were produced on plants of soybean subjected to mulch treatment. The yield of *Glycine max* was affected significantly and a reduction in yield was registered for tree + crop, tree pruned +crop, tree pruned + mulch +crop over sole crop (Table- 24). The earlier

findings of Bisaria *et al.*, (1998), and Solanki *et al.*, (1999), also reported a reduction in the yield of *Vigna radiata* and *Glycine max* respectively, due to *Leucaena leucocephala.* They reported inhibitory effect of *Leucaena leucocephala* on the yield parameters of the intercrops over the sole crop. However, the seed yield enhanced under the treatment crop + mulch as compared to sole crop. This may be attributed to the factor that *Leucaena leucocephala* mulch contains some growth enhancing substances and being a nitrogen fixing tree it helps in increasing the seed yield of *Glycine max,* when applied to the crop. The minimum reduction due to pruning of trees and mulch application suggests that the yield of intercrop can be managed with these practices. These results obtained were in line with the findings of Tripathi et al (1998), who reported that growth of *Glycine max* was enhanced due to the management practices even in the presence of *Acacia nilotica* over the sole crop treatment.

The trend for yield parameters for *Triticum aestivum* was similar to that reported for the growth parameters and yield parameters of *Glycine max*. The data revealed that the phenomenon of tiller production in *Triticum aestivum* was significantly inhibited due to *Leucaena leucocephala.* The reduction imposed by the tree component was counteracted to some extend by pruning and further curtailed by addition of mulch and pruning together. The maximum and minimum number of effective tillers were recorded in the treatment crop + mulch and tree + crop respectively (Table- 26). The maximum number of non effective tillers were produced in treatment of tree + crop and in other treatment the value were not significant, this may be attributed to the fact that due

to *Leucaena leucocephala* the reduction in yield parameters was more pronounced than that observed for vegetative parameters. The inhibitory effect of *Leucaena leucocephala* on *Triticum aestivum* was in line with the observations reported earlier on *Zea mays*,(Field and Matan, 1990), *Triticum aestivum* and *Vigna radiata* (Deb Roy and Gill,1991) *Sorghum bicolor* (Korwar and Radder, 1991), *Zea mays*, *Triticum aestivum* (Chaturvedi and Jha,1994),*Vigna radiata*, *Emblica officinalis* (Bisaria *et al.*, 1998) *Glycine max* (Solanki *et al.*,1999).

The yield recorded for *Triticum aestivum* was minimum for tree + crop treatment repeating the trend observed for all other parameters, but was confirmatory to earlier reports. In favour of these results Gill (1995), reported that under the *Populus* species the yield of *Triticum aestivum* reduced, similarly reduction was also observed in the yield of *Triticum aestivum* under *Acacia nilotica* (Dalal *et al.*,1992).

The maximum yield of *Triticum aestivum* was recorded when mulch was applied to the intercrop and reduction was also minimised due to mulching and pruning even in the presence of *Leucaena leucocephala.* The present findings suggests that productivity can be enhanced even in the presence of *Leucaena leucocephala* due to proper management practices (Fig. -3). These observations were in line with those reported earlier for *Zea mays, Sorghum bicolor, Trifolium repens* and *Aveana sativa*(Gill and Patil,1981;Gill *et al.*, 1992; Parihar, 1990; 1994)who reported the stimulatory effect, *Zea mays*,(Macklin *et al.*,1988), *Zea mays*,(Pathak,1988), *Sorghum bicolor*(Wiegard and Jutzi, 1996), *Triticum aestivum* (Sharma *et al.*, 1997). Similarly, Rao and

Reddy, (1984) reported stimulatory effect on yield of *Triticum aestivum, Pennisetum typhoides* and *Coriandrum sativum* when intercroped with *Eucalyptus globulus*.

The present finding that yield was maximum under crop + mulch treatment and that reduction in crop yield was checked through the application of mulch in association with tree may be attributed to the fact that mimosine related compound in decomposed leaves is present in the form of 3-hydroxy-4 pyridone, which is considerably more stable than 3,4-dihydroxy pyridine and it also limits the degree of mimosine activity and eliminated the inhibitory influence of mimosine when it comes in contact with iron due present in mulch. Thus resulted in maximum growth and yield productivity under this treatment. Earlier Tawata and Hongo (1987), also reported that mimosine in the form of 3-hydroxy-4 pyridone present in dried leaves of *Leucaena leucocephala* exhibited no inhibitory effect in presence of iron due to chelating bond.

The experimental finding of the present studies concluded that the *Leucaena leucocephala* exhibited an inhibitory effect on both the intercrops i.e. *Triticum aestivum* and *Glycine max* when no management practices were followed, but when we applied he mulch of *Leucaena leucocephala* to the crop, the effect changed from inhibitory to stimulatory nature. The effect was more pronounced during second year of experimentation as compared to first year.

Chemical analysis of leaves : The results obtained for the chemical analysis of leaves of *Leucaena leucocephala* revealed that their was no significant difference in values of N, P and K during two years. The maximum nitrogen was estimated in treatments tree pruned

supplemented with mulch and crops (4.38%) and the minimum amount of nitrogen was recorded in leaves of trees + crop (4.09%). Similar trend was exhibited in case of phosphorus and potassium (Table-28). This was perhaps due to the fact that treatment of mulch application enhanced the N, P and K content in the leaves for that treatment. Earlier studies of some workers like D'Mello and Thomas (1978) and Jones and Jones (1983) also reported similar type of changes in the chemical composition of leaves of the Leucaena species. There result showed that application of mulch significantly increased the nutrients (N, P and K) in leaves of *Leucaena leucocephala* as reported earlier by Kleinjans (1984) and D'Mello and Fraser (1981). The crude protein estimation of leaves (Table -29) revealed that maximum crude protein content was recorded fro tree pruned + mulch + crop treatment (22.90 % and 22.97 %) during both the years and minimum value for tree + crop (20.98 % and 21.03 %) treatment during 1997-98 and 1998-99. This may be due to the fact that mulch application in association with pruning increased the crude protein content of the leaves. In general there was no significant difference for crude protein content between different treatments these findings are in line with those earlier reported by James *et al.* (1987), that there was slightly higher protein content in young leaves than mature, therefore the pruning resulted in new flush of leaves which may be responsible for little higher content of crude protein in pruned treatments.

Changes in soil organic carbon, available Nitrogen, Phosphorus and Potassium : The studies conducted for changes in soil nutrients (Table-30)during the experimentation revealed that organic carbon, available

nitrogen, phosphorous and potassium contents in the soil after the termination of the experiment increased to 0.54%, 241.62, 17.27, 325.94 kg/ha, over the initial value of 0.46%, 214.85, 15.19 and 298.70 kg/ha, respectively. This may be due to application of mulch in some treatments of the experiment resulting in an increase in these contents and *Leucaena leucocephala* being a nitrogen fixing tree. Earlier Kleinjans (1984) and Jones and Jones (1983) also reported the similar type of findings confirming the present results.

TENTATIVE HYPOTHESIS

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The critical perusal of the experimental findings of the present investigation entitled "Allelopathic potential of subabul (*Leucaena leucocephala* (Lam.) de Vit." in relation to agroforestry exhibits a wide spectrum of allelopathic influence of *Leucaena leucocephala* on the intercrops. The aqueous extracts of leaves, flowers, pods and decomposed leaves promoted seed germination and seedling growth up to a concentration of 40%, higher concentrations (80 and 100%) drastically inhibited seed germination and seedling growth and 60% concentration had no significant effect on these attributes, both in *Glycine max* and *Triticum aestivum.* The inhibitory influence of pod extract on seed germination and seedling growth was more pronounced as compared to leaves, flowers and decomposed leaves. *Leucaena leucocephala* has been reported to contain mimosine, a non-protein amino acid, which is an allelopathic chemical. It appears that the presence of mimosine and its quantity might play a pivotal role in regulation of seed germination and seedling growth. The decisive role of mimosine in seed germination was confirmed by the analytical studies of leaves, flower, pods and decomposed leaves which revealed that pods and decomposed leaves contained maximum and minimum amount of mimosine, respectively. The sequence of quantityof mimosine was pods (7.13%) > flower (6.87%) > fresh leaves (5.23%) > decomposed leaves (4.61%).

Further, the influence of decomposed leaves and field soil in four combinations was studied in nursery. These studies revealed that maximum and minimum seed germination and seedling growth was

observed in 1: 3 ratio and 100% of *Leucaena leucocephala* soil, respectively in both the tested crops. However, the inhibition of seed germination and seedling growth was more pronounced in *Glycine max* as compared to *Triticum aestivum*.

Field studies revealed that the growth of *Leucaena leucocephala* was not affected significantly due to companion crops during the two years of experimentation. However, leaf temperature and relative humidity of *Leucaena leucocephala* were increased due to intercrops. The PAR for intercrops was reduced by the canopy of *Leucaena leucocephala.* The leaf temperature and relative humidity of intercrops were increased and rate of transpiration remained unaffected due to the canopy of tree component.

The growth attributes of intercrop *viz.* height, number of branches for *Glycine max* and number of tillers for *Triticum aestivum* were reduced by the tree component. The aforesaid parameters were significantly increased when crop was supplemented with mulch. *Leucaena leucocephala* reduced the yield of intercrops, however, the reduction potential was higher during the second year of the experiment.

The experimental significance suggested that the phenomenon of allelopathy may not be a common explanation for delayed seed germination, retardation of seedling growth and reduction in productivity. The allelopathy have a pronounced effect on concurrent systems like agroforestry, where tree component is a permanent feature and releases allelochemicals (secondary metabolism) into the environment which directly or indirectly affect the companion crops/ and vegetation.

The important allelopathic chemical *viz.* mimosine, an amino acid,

quercetin, gallic acid, ferculic acid and verulic acid are released by tree of *Leucaena leucocephala* into the environment through leaching, root exudation and decomposition of leaves and roots.

It appears from the experimental finding that intercrops are affected by *Leucaena leucocephala* mainly through two ways firstly by the canopy of tree, which curtails solar radiation and subsequently suppressed growth and reduced the yield of intercrops and secondly, by allelopathy. The allelopathic influence of *Leucaena leucocephala* on *Glycine max* and *Triticum aestivum* is mediated mainly through mimosine, which perhaps lead to stimulation of seed germination, growth and productivity at lower concentration and inhibition of these attributes at higher concentrations. It suggests that the mimosine has a wide spectrum of its influence and also plays a decisive role in manipulation of the growth and yield attributes of the companion crops. Therefore, magnifying the seedling growth and productivity potential of intercrops at lower concentrations. The mulch application of *Leucaena leucocephala* containing low concentrations of mimosine increased the yield of intercrops by improving physical and chemical status of soil. Similarly, pruning of the tree component enhanced the growth and productivity of intercrops, confirming that *Leucaena leucocephala* affects intercrops through canopy competition and allelopathy.

RECOMMENDATIONS :

Leucaena leucocephala is a suitable tree species for the agrisilvicultural system. However, trees should be pruned upto 50% from ground level and the leaf biomass should be incorporated into the field as mulch for the redressal of advance effect of *Leucaena leucocephala* and to optimum growth and yield of the intercrops.

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PICTORIAL SECTION

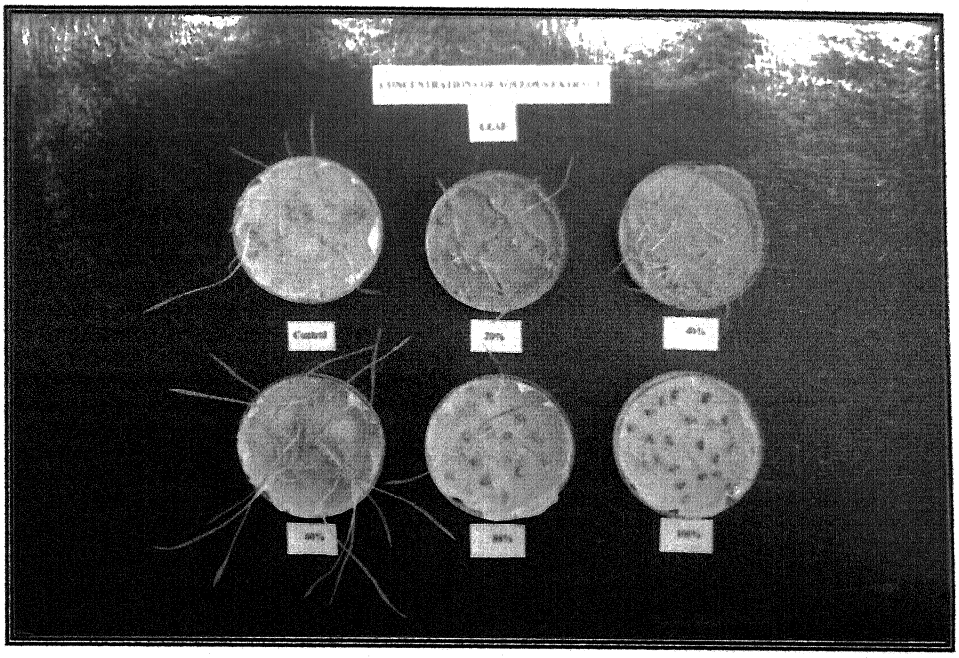


Photo plate -1 : Effect of fresh leaves aqueous extract of *Leucaena leucocephala* on the seed germination in *Triticum aestivum*

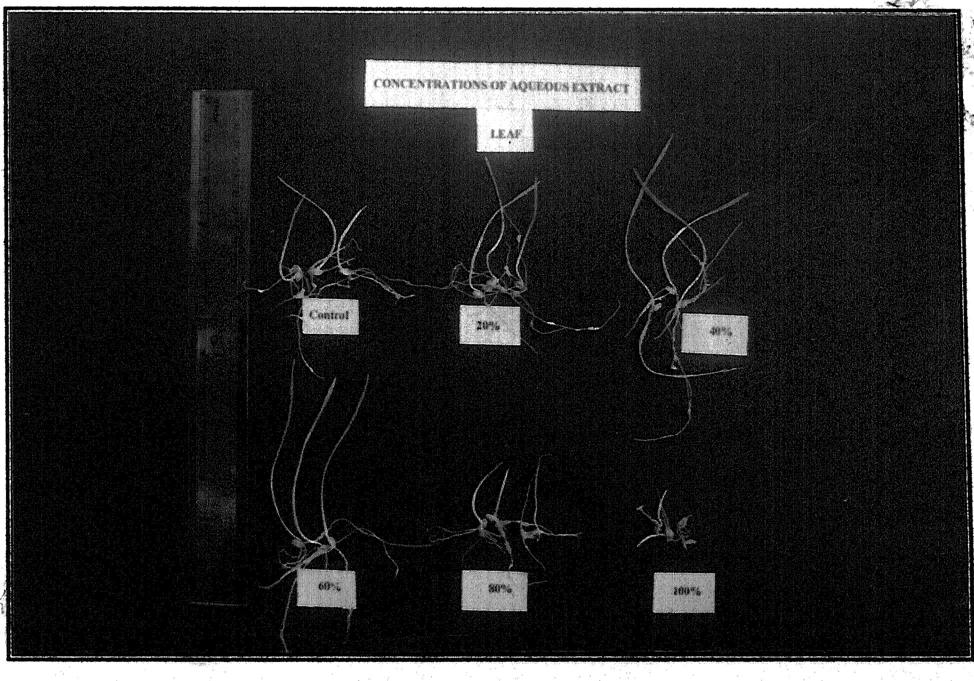


Photo plate - 2 : Effect of fresh leaves aqueous extract of *Leucaena leucocephala* on the seedling growth in *Triticum aestivum*

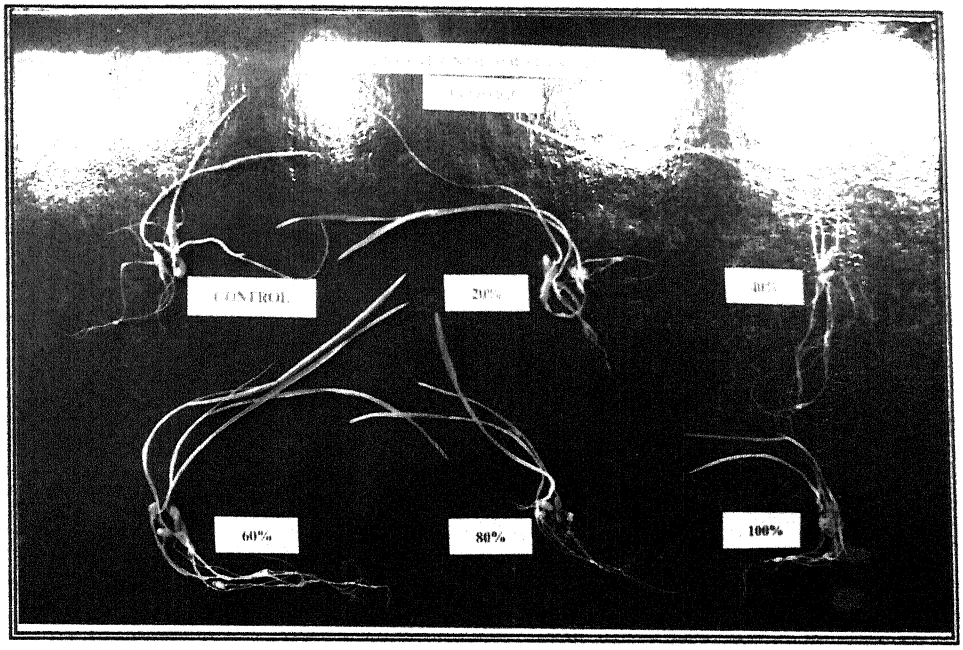


Photo plate - 3 : Effect of flower aqueous extract of *Leucaena leucocephala* on the seedling growth in *Triticum aestivum*

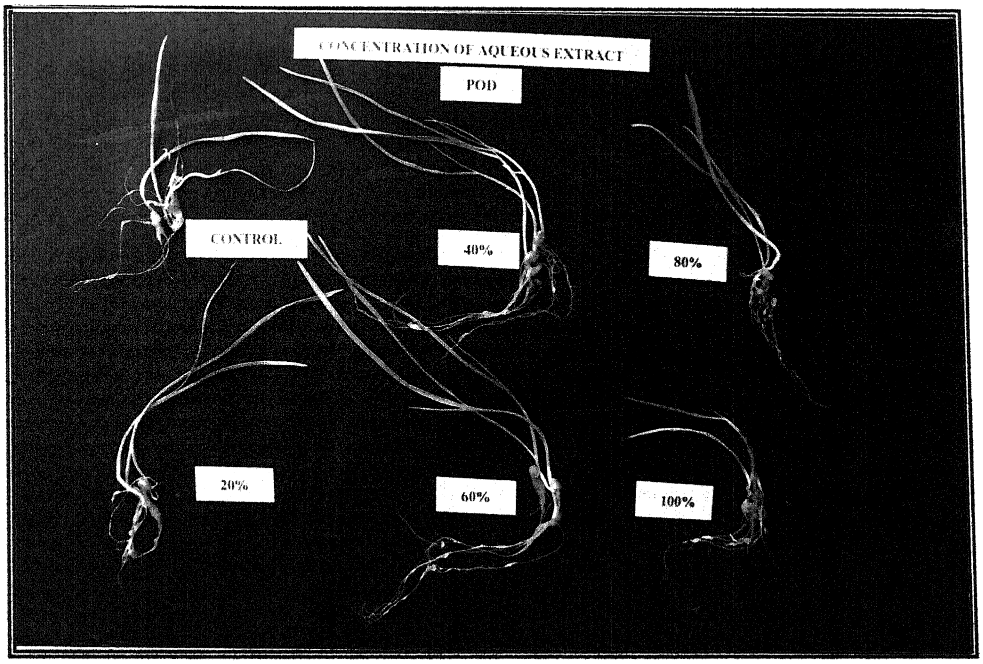


Photo plate - 4 : Effect of pod aqueous extract of *Leucaena leucocephala* on the seedling growth in *Triticum aestivum*

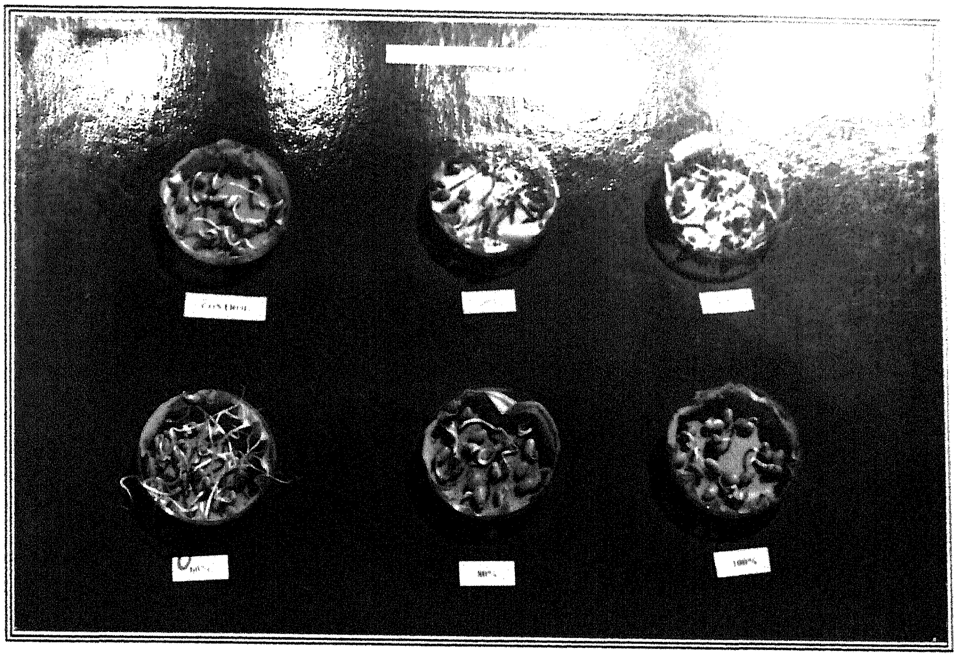


Photo plate - 5 : Effect of fresh leaves aqueous extract of *Leucaena leucocephala* on the seed germination in *Glycine max*

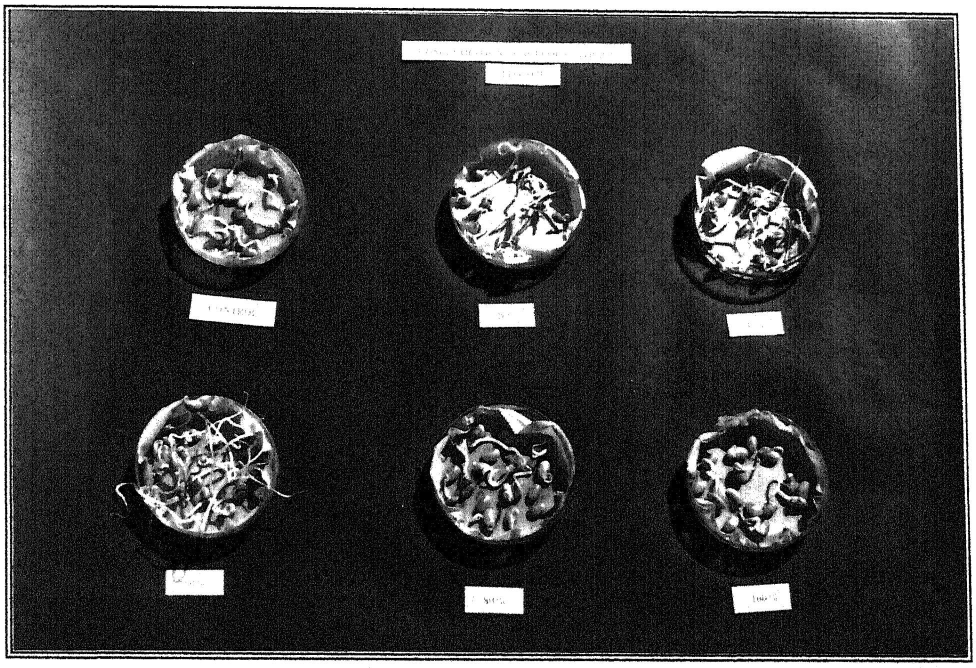


Photo plate - 6 : Effect of flower aqueous extract of *Leucaena leucocephala* on the seed germination in *Glycine max*

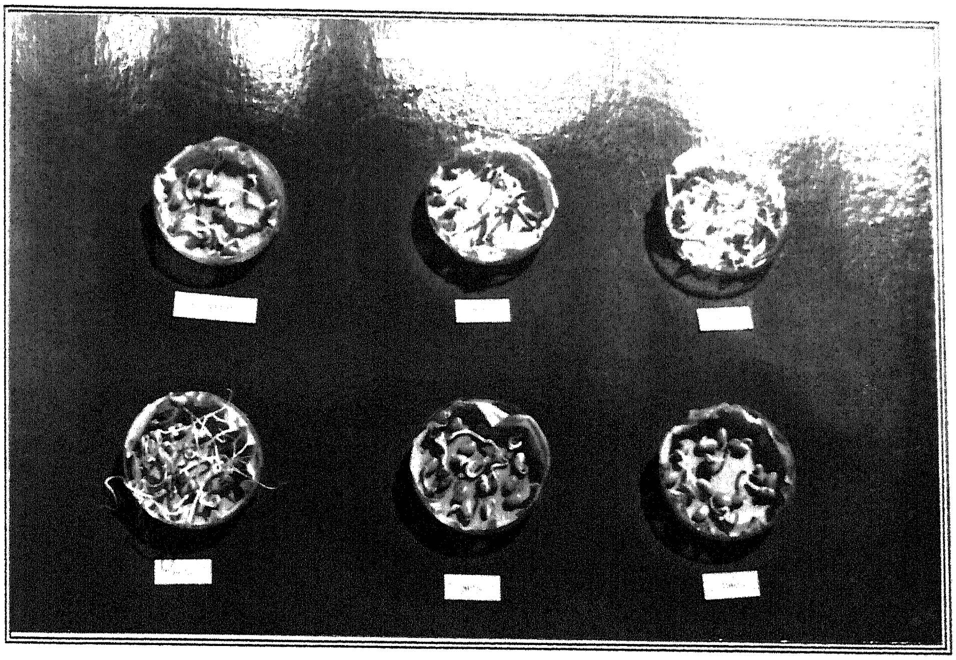


Photo plate - 7 : Effect of pod aqueous extract of *Leucaena leucocephala* on the seed germination in *Glycine max*

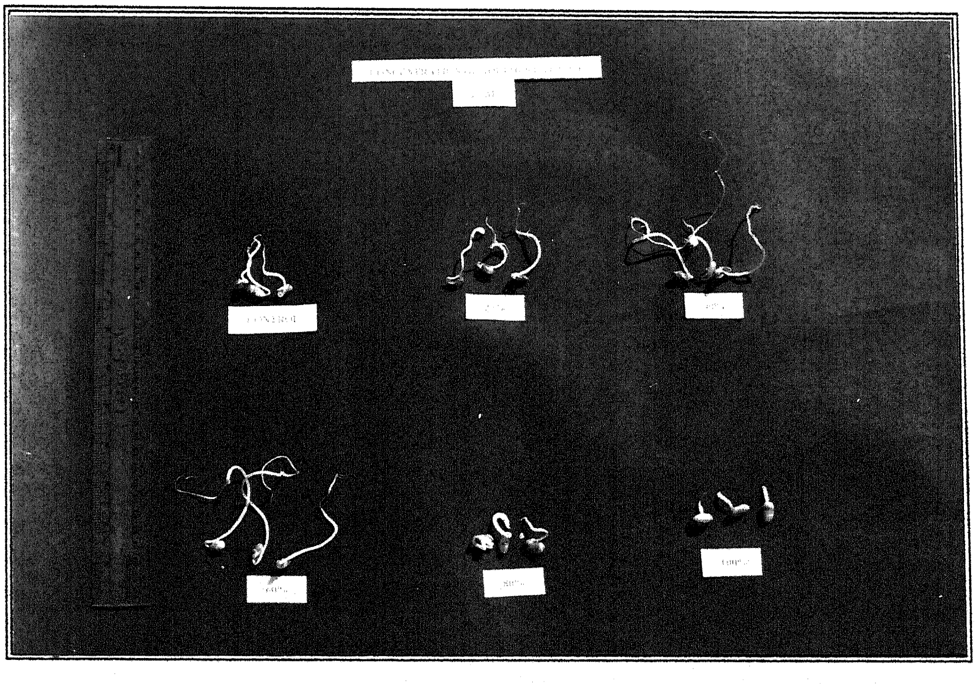


Photo plate - 8 : Effect of fresh leaves aqueous extract of *Leucaena leucocephala* on the seedling growth in *Glycine max*

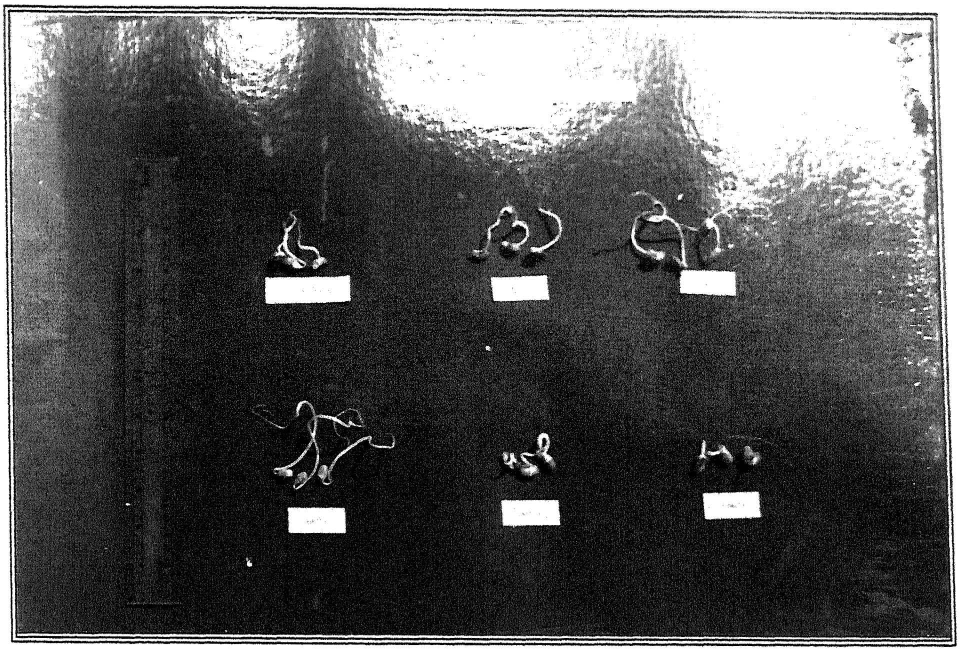


Photo plate - 9 : Effect of flower aqueous extract of *Leucaena leucocephala* on the seedling growth in *Glycine max*

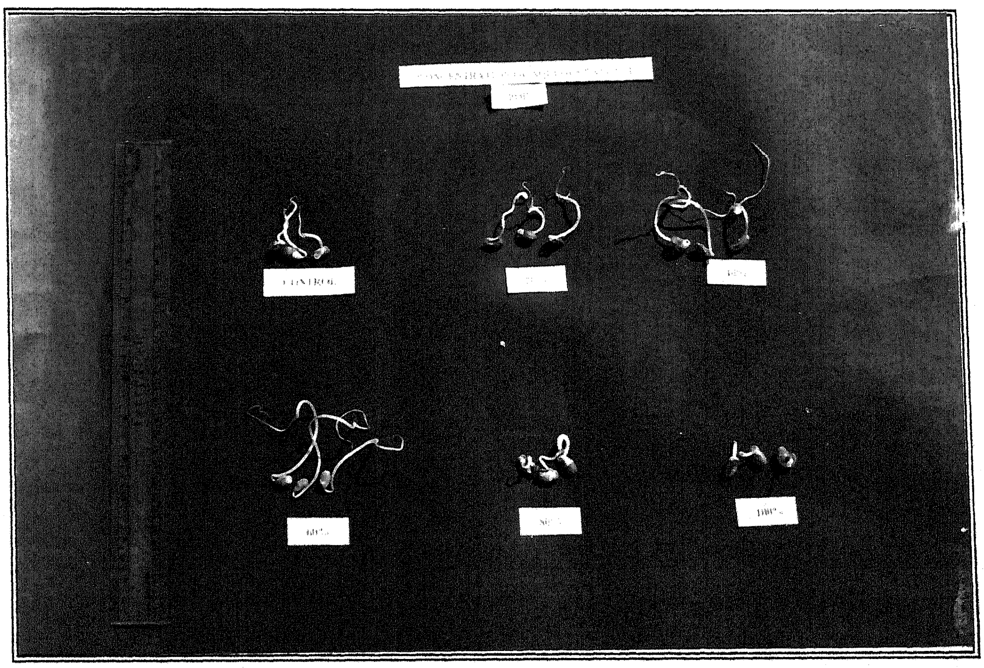


Photo plate - 10 : Effect of pod aqueous extract of *Leucaena leucocephala* on the seedling growth in *Glycine max*

Photo plate - 11 : Effect of different soil combinations on seed germination of *Triticum aestivum* under nursery conditions

Photo plate -12 : Effect of different soil combinations on seed germination of *Glycine max* under nursery conditions

Photo plate - 13 : Effect of different soil combinations on seedling growth of *Glycine max* under nursery conditions

Photo plate - 15 : A view of sole crop of *Triticum aestivum*

Photo plate -16 : Effect of pruning of trees on growth of *Triticum aestivum*

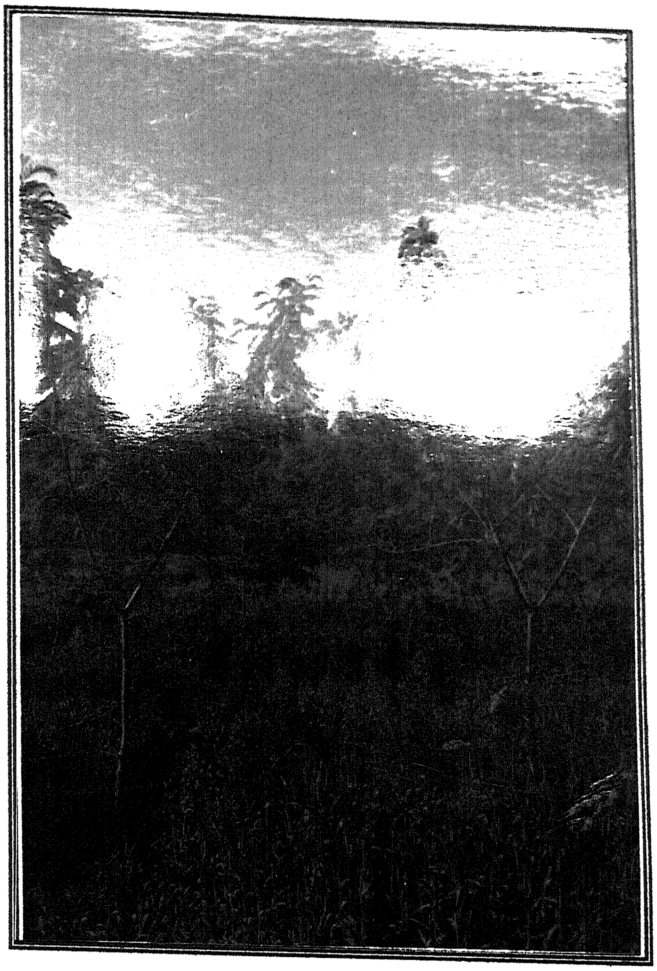


Photo plate - 17 : Effect of pruning of trees and application of mulch on growth of *Triticum aestivum*

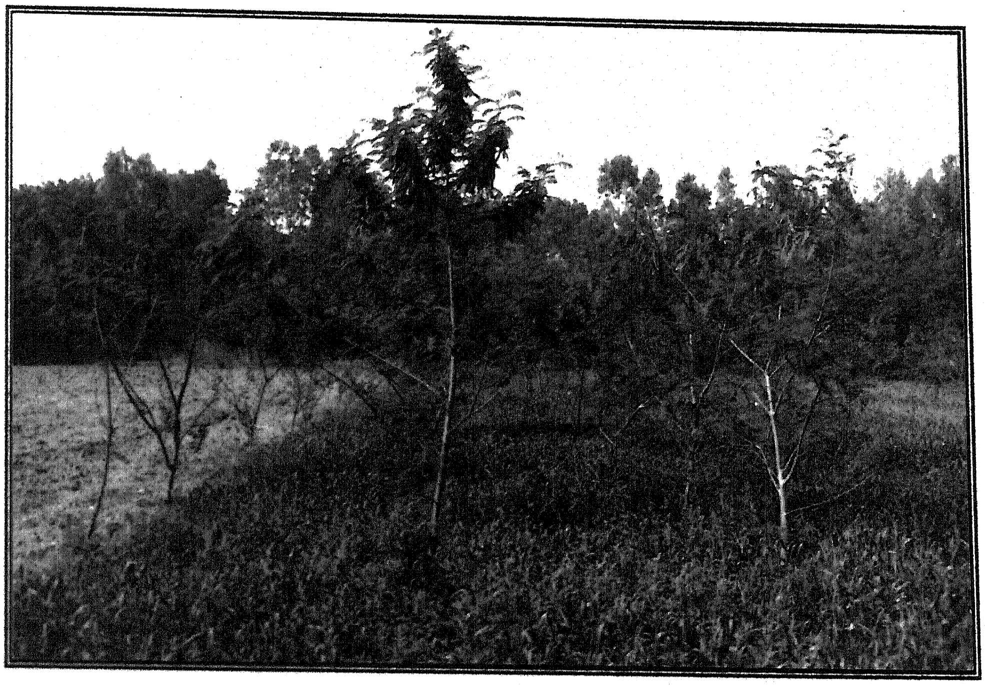


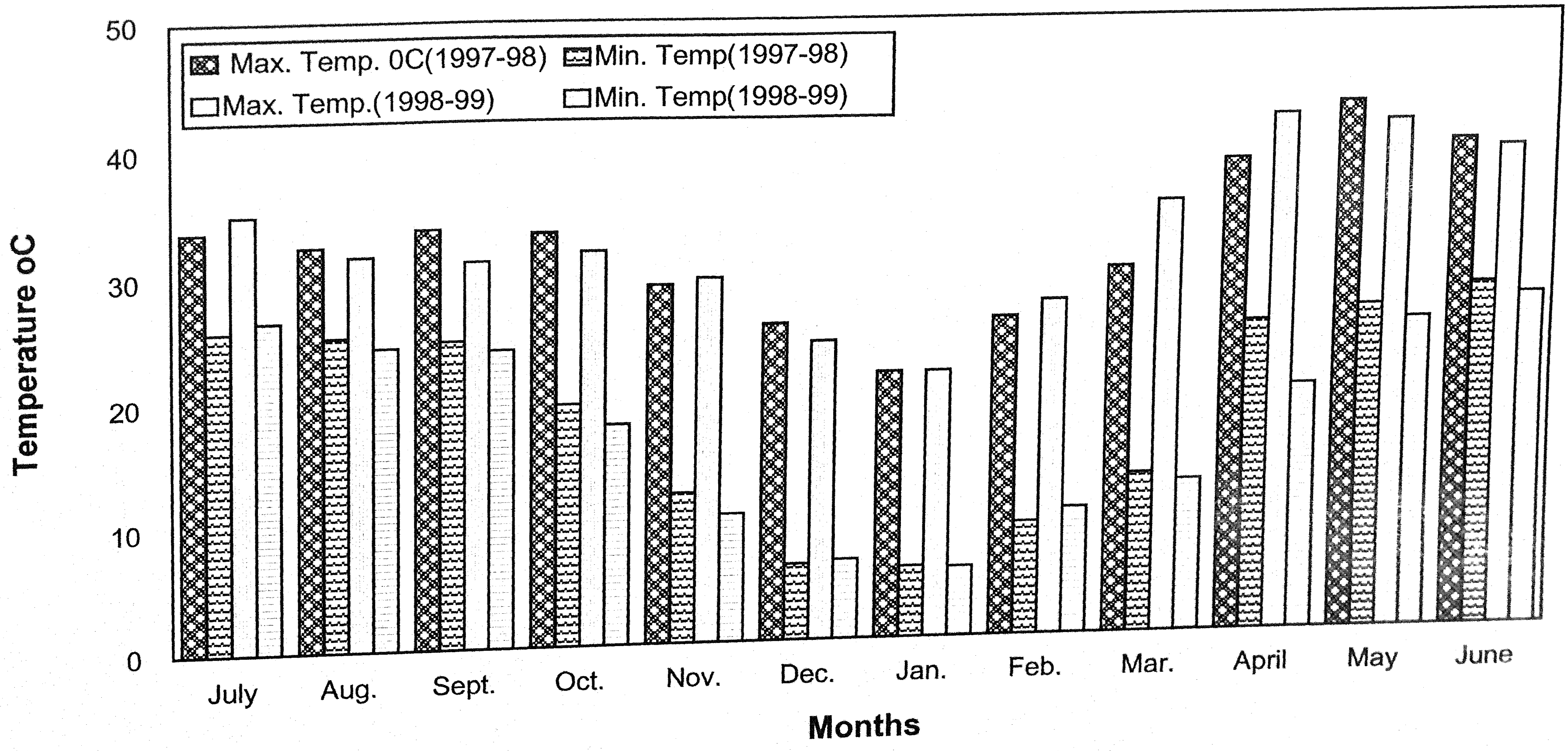
Photo plate - 18 : Effect of trees on growth of *Triticum aestivum*

Photo plate - 19 : A view of gummosis in *Leucaena leucocephala*

Photo plate -20 : A general view of field experiment

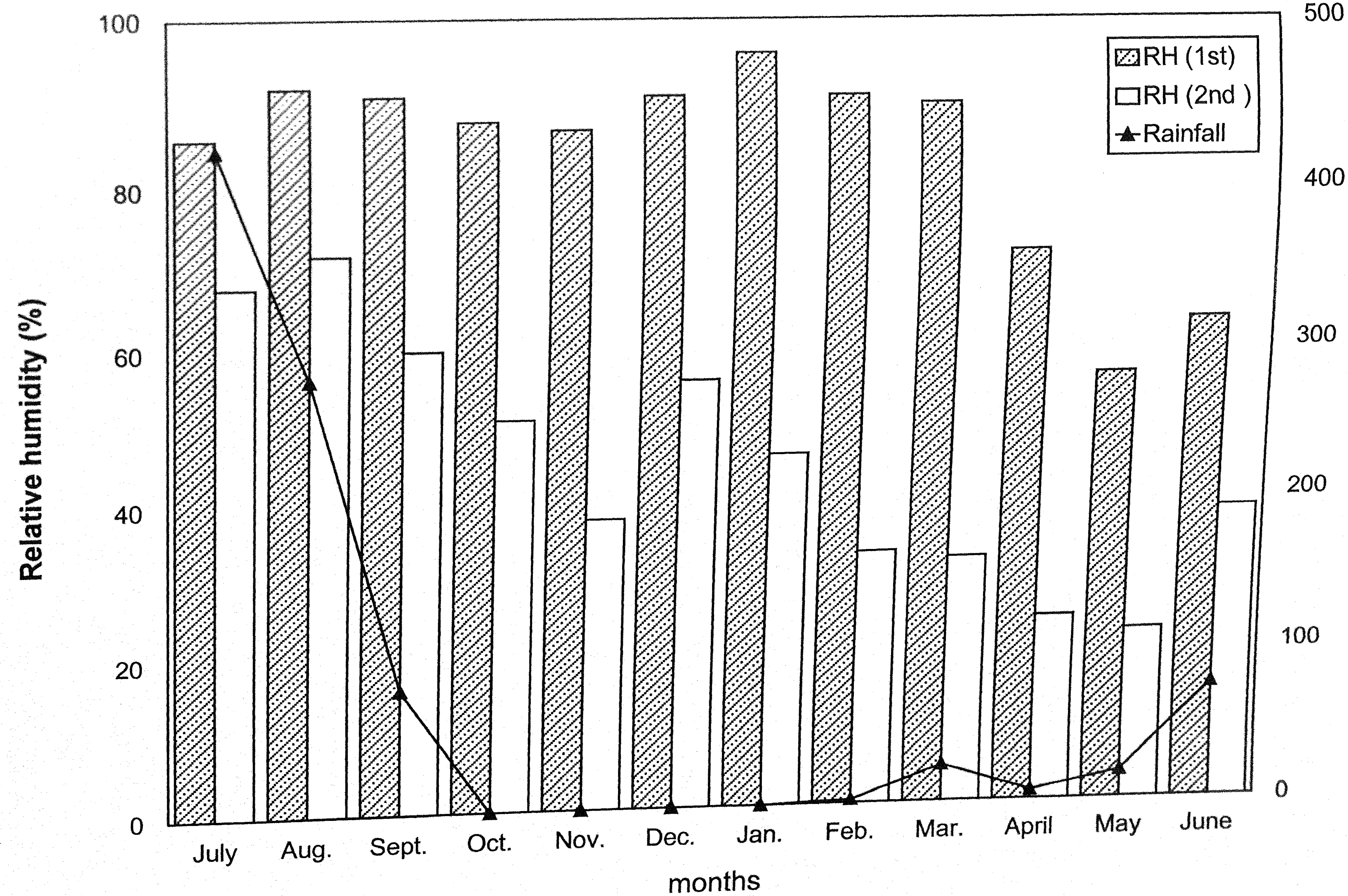
ANNEXURE

ANNEXURE - I



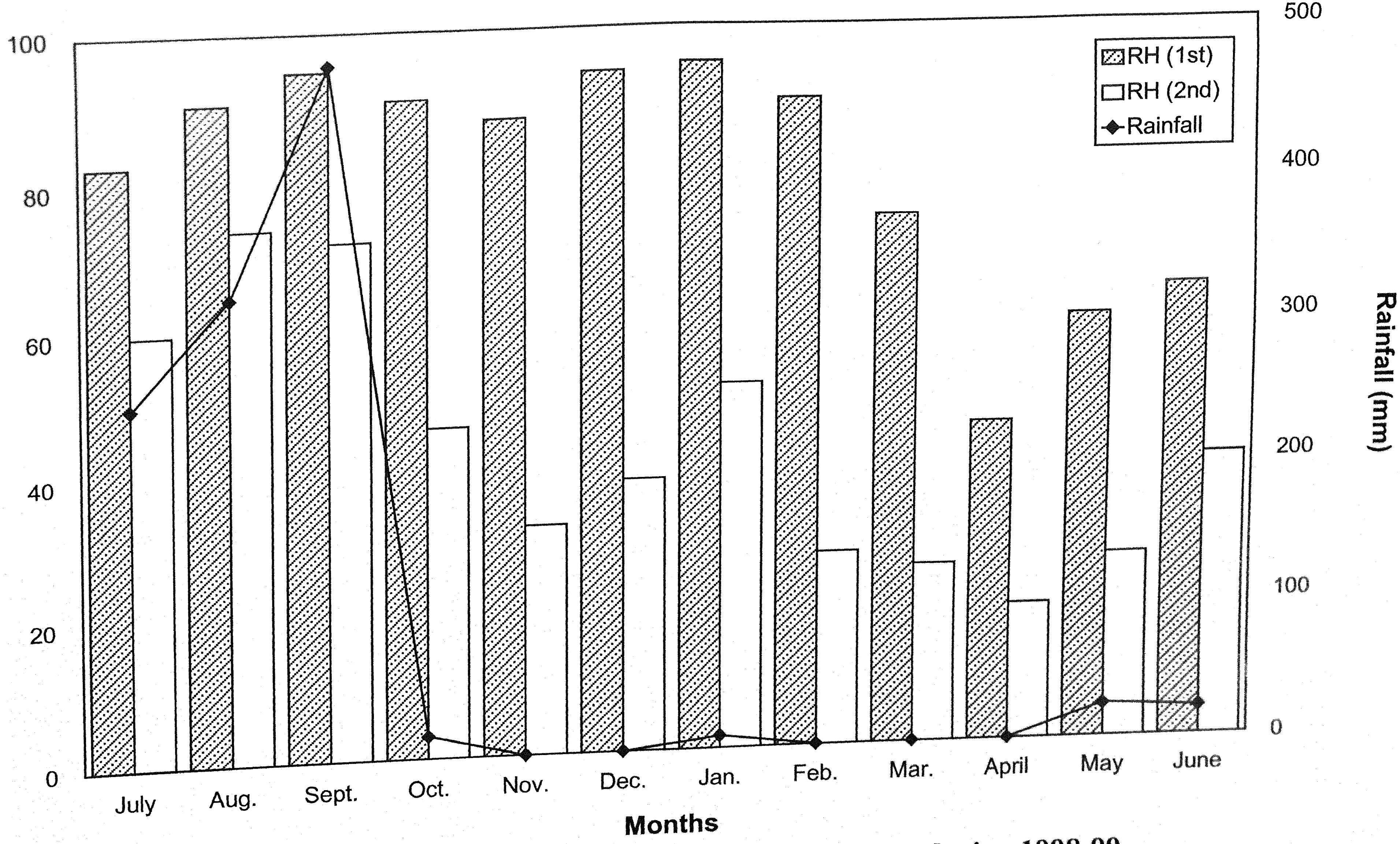
Temperature data of experimental site during 1997-98 and 1998-99

ANNEXURE - II



Rainfall and Relative humidity of the experimental site during 1997-98

ANNEXURE - III



Rainfall and Relative humidity of the experimental site during 1998-99

Symbols and Abbreviations used in Text

Symbol/Abbreviation	Full Name
'	Minute
>	Greater then
@	At the rate of
^{o}C	Degree centigrade
μ	1/1000 millimeter
mm	Millimeter
cm.	Centimeter
m	Meter
ha	hectare
mg	Milligram
g	Gram
kg	Kilogram
q	Quintal
ml	Milliliter
s	Seconds
K. cal kg^{-1}	Kilo calories per kilogram
rpm	Round per minute
O.D.	Optical density
DBH	Diameter at breast height
C.D.	Critical difference
N	North
E	East
BHC	Benzene hexa chloride
FYM	Farm yard manure
DAP	Diammonium phosphate
MOP	Morato potash
N	Nitrogen
HCl	Hydrochloric acid
$FeCl_3$	Ferric chloride
H_2SO_4	Sulphuric acid
K_2SO_4	Potassium sulphate
$CuSO_4$	Copper sulphate
$KMnO_4$	Potassium permagnate
SC	Sole crop
ST	Sole tree
TC	Tree + crop
TP	Tree pruned
TP + C	Tree pruned + crop
TP+M	Tree pruned + mulch
TP+M+C	Tree pruned + mulch + crop